School of GeoSciences

Cycling risks communication using Web-GIS: different visualisation techniques and their effectiveness

DISSERTATION

For the degree of

MSc in Geographical Information Science

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I declare that this dissertation represents my own work, and that where the work of others has been used it has been duly accredited. I further declare that the length of the components of this dissertation is 5356 words for the Research Paper and 6324 words for the Technical Report

Signed: _____________________________ 06/08/2014

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PART I

Abstract

Scottish Government has been committed for many years to encouraging cycling as main private means of transport, in 2008 1% of all Scottish travel were made by bicycle, the vision is to increase this rate to 10% by 2020. In 2012, 2% of travels between 3 and 5 km in Scotland were made by bicycle, the goal is actually far but in the meantime we are noticing that cycling has become more and more popular in daily commute, especially in urban environments where its rapid growth has usually been associated with safety problems. In Scotland and UK between 2011 and 2012 the number of people injured in accidents involving bicycles has raised. Reducing casualties is therefore a primary objective sought by public institutions at any levels. I will explore innovative visualisation techniques and I will elaborate a safe route planner able avoid critical areas where cycling accidents tend to cluster. Bicycles collisions data from 2005-2012 are provided by Department for Transport. A safe route choice model will make use of information derived from this dataset to optimise a least cost path algorithm for the route planner. Effectiveness of the route planner will be tested to assess the risk reduction and to evaluate how conceived risk communication techniques succeed at generating awareness in experienced and non-experienced cyclists. The first test will actually highlight the success of the model while users will responses will vary according to their cycling experience. The research will fill gaps regarding cyclist aimed web-GIS services and at the same time will point out how the communication and perception of risk might be taken into account for further research.

1. Introduction

The level of cycling in the UK is one of the lowest among the most developed countries. In contrast to the Netherlands and Germany, in the UK the number of cyclists declined from the mid '70 to 2008 when just 1.3% of trips were done by bicycle (Pucher, 2008). Despite these figures cycling has always been encouraged by UK government institutions; for example, the vision of the Cycling Action Plan for Scotland (CAPS) is to rise the number of journeys taken by bicycle up to 10% in 2020 (CAPS, 2013) when in 2012 those journeys were just the 1.3% of the total, in line with UK (Transport for Scotland, 2013).

In the light of the principles of sustainability which have been established since the end of the past century (United Nations, 1992) and confirmed in the course of the years to come until the most recent conference on sustainable development, Rio +20 (United Nations, 2012), cycling is defined as a sustainable transport means (Black, 1996) capable of providing environmental benefits such as reducing motor vehicles traffic, transport emissions and greenhouse gases (de Hartog et al., 2010).

In terms of benefits of cycling, there is not a universal consensus whether those always overcome risks; exposure to traffic exhausts demonstrated to have adverse outcomes (Bos et al., 2013) and likelihood to incur accidents can also be considered an important source of risk. For example in the Netherlands, cyclists are 5.5 times likelier than car drivers to incur an accident per kilometre travelled (de Hartog et al., 2010).

It is evident that interventions from various authorities in urban environments to favour the so called "shift" from motor vehicles to bicycles (Ogilvie, 2004) must deal with cycling accidents and develop strategies for their reduction; especially if we think that accidents risk is a major deterrent from cycling (Parkin et al., 2007; Winters et al., 2011).

1.1 Research aim and objectives

In this dissertation we will focus on the ability of Geographic Information Systems to communicate accidents risk awareness to their users. We will just use accidents data for the city of Edinburgh, publicly available from UK Department For Transport (DfT), and explore the possibilities offered by current web/mobile applications in order to focus our scope and identify potential gaps. We want to understand from final users how it is possible to communicate risks with these data and test if GIS technologies can be considered effective for this purpose.

In order to achieve this aim the main objectives are:

- Provide a general understanding of how risk can be communicated.
- Assess veracity of various visualisations.
- Develop longitudinal visualisation techniques applied to a case study area.
- Evaluation of model outputs through questionnaire analysis.

2. Review of GIS services communicating cycling accidents risks

The World Wide Web has now become one of the most powerful communication tool, GIS has been one of the beneficiaries of this, with a huge development and lots of web based GIS (Longley, 2011). The power of web is its large diffusion and the high immediacy with which it displays data. Similarly, the rise of the use of mobile devices has further increased the popularity of distributed spatial data. One of the decisive differences between desktop solutions and mobile are that latter can benefit from the use of Global Positioning System GPS able to locate users' position and to enable related services and functionalities. We will now cite examples of both technologies that use Reported Road Casualties in Great Britain (UK DfT, 2013).

2.1 Web services functionalities

CycleStreets is a well-known web and mobile cycling route planner; it originates from a project launched by Cambridge Cycling Campaign; initially available just for that area, it then has geographically expanded its scope until becoming national and city-focused; there is an Edinburgh specific version which development was partly funded by Transport Scotland (Edinburgh CycleStreets, 2014). The map service uses OpenStreetMap road network and OpenCycleMap layout; the base map shows hills contours and cyclists points of interest. CycleStreets has its collisions section (www.cyclestreets.net/collisions); there we can find an accidents map (from 2005 to 2010) which main functions are single accident reports, including Google street view of the approximate point of collision, textual reports for specific areas drawn by users and a utility to query the accidents database (see figure 1).

The CycleStreets route planning offers the user the choice of three types of routes, fast, balanced and quiet, directions turn by turn and an indicator for the overall quietness of the route (see figure 2 and 3). Quiet routes tend to favour cycle paths and residential roads, however there is no relationship between the accidents database and the routing algorithm, designed routes do not account for accidents as a source of risk.

Another web application which is worth to mention, even if it does not use our data, is the map and routing planner provided by OPT for health (http://opt.berkeley.edu/), this map is part of a wider project of U.S. National Institute of Health aimed at assessing the effectiveness of a governmental programme aimed at improving nutrition and physical activity for children and their families. Past accidents are not shown on the map but it is possible to find optimal bicycle routes on the basis of criteria that users can choose and weight, among these we can find the location of past bicycles/pedestrians accidents (see figure 4).

If we consider mobile applications we can actually find a lot of apps designed for cyclists, at the same time we can just see a significant complete lack of mobile based applications using locations of bicycles collisions, least of all the dataset we will use in our research.

2.2 Web services Visualisation techniques

We also explored other web services visualisation techniques, to understand how risk is communicated by existing tools but also to identify potential gaps we could fill. Other Web-GIS resort almost exclusively to punctual features, different sizes and hues indicate quantitative and qualitative differences, (Krygier and Wood, 2005) on the basis of Jacuqes Bertin (1967). If we look at table 2 we can understand how communication of roads risks through maps in the UK is not completely explored; considering the possible visualisation alternatives, identified by the aforementioned authors, gaps are evident.

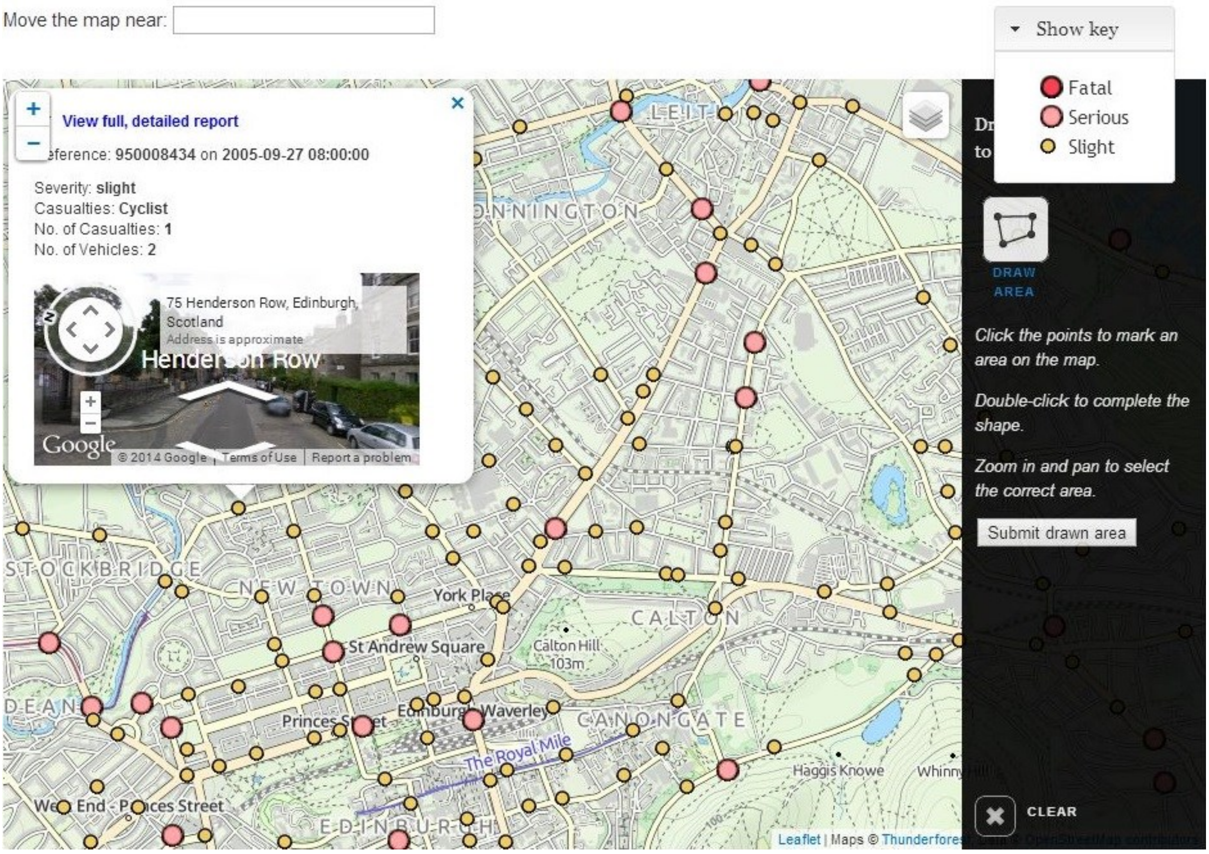


Figure 1: CycleStreets collisions map

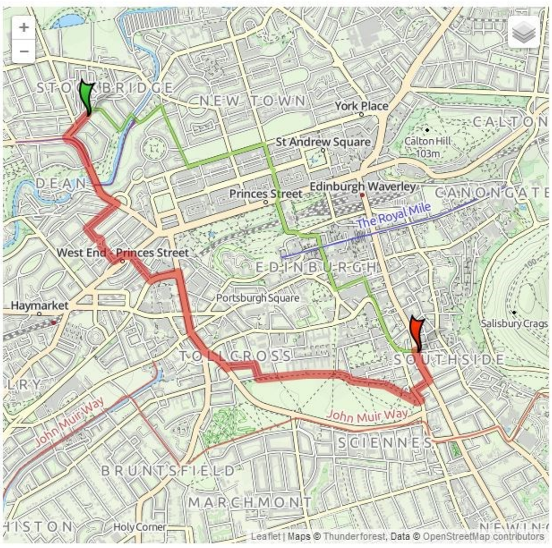


Figure 2: CycleStreets fastest route example

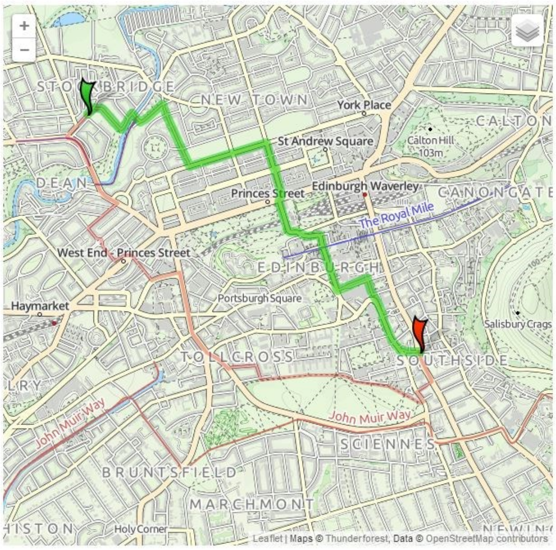


Figure 3: CycleStreets quietest route example

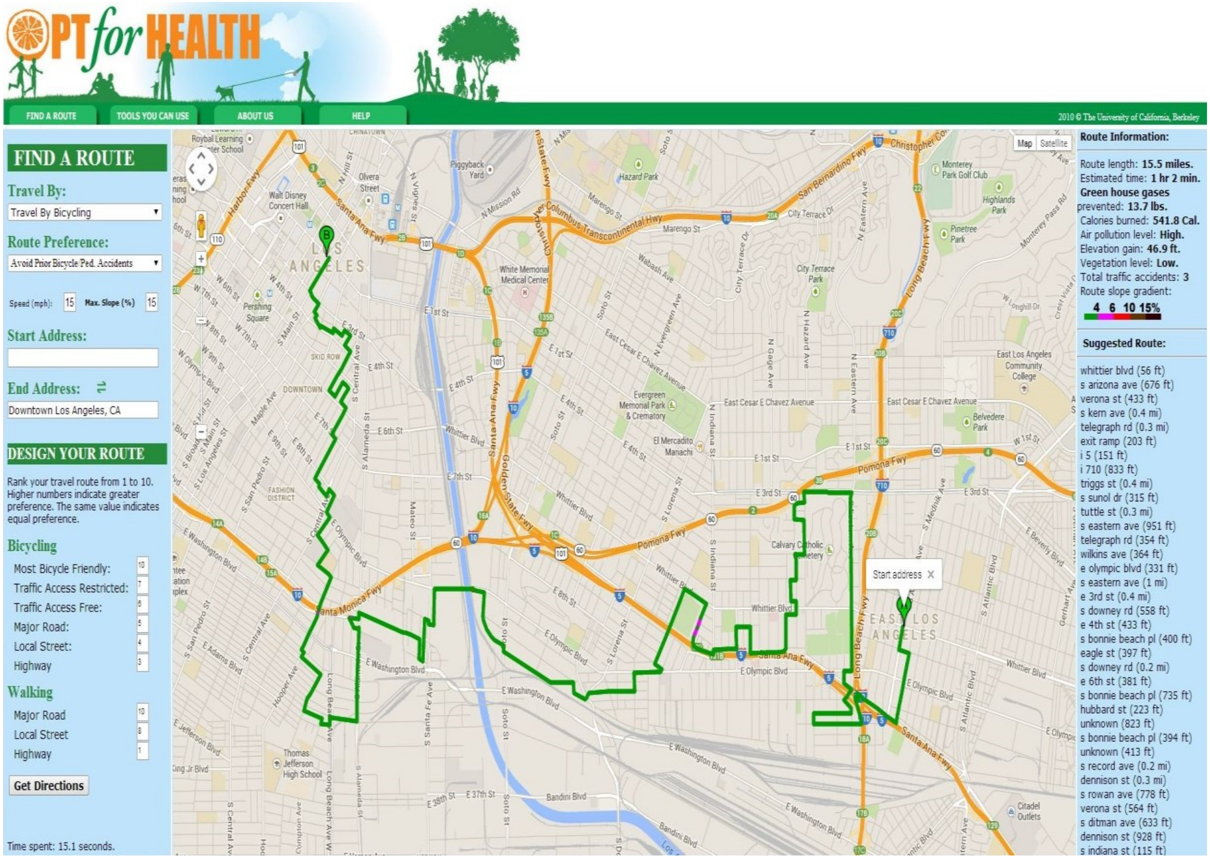


Figure 4: OPT for health safe bicycle routing planner

Table 1: Other relevant web-GIS services for UK road accidents

NAME	URL	SINGLE ACCIDENT REPORTING	USER SELECTED AREA	ROUTING	INFORMATION	AREA	TIME
CrashMap	http://www.crashmap.co.uk/	Complete but upon payment	No	No	Date, severity, number of vehicles and casualties involved	UK	2006 - 2012
Osbornes Solicitors LLP	http://www.osbornes.net/ukroadaccidentmap	Not complete	No	No	Date, time, severity, number of casualties, age of casualties, sex, intersection type, speed limit, light condition, weather condition, road condition, presence of police on location	UK	2011
CityBeast	http://citybeast.com/cyclistsscotland.html	Not complete	No	No	Date, time, casualty sex, type of vehicles involved	Scotland	2000 - 2008
DfT Accident Map	http://road-collisions.dft.gov.uk/	Not complete	No, but allows county based report	No	Year, severity, number of casualties, number of vehicles, type of vehicles involved	England	2005 - 2012
BBC News UK	http://www.bbc.co.uk/news/uk-15975720	Not complete, fatal accidents only	No, but allows county based reports	No	Date, time, number and type of vehicles involved, number of casualties, age, sex and weather conditions	UK	1999-2010

Table 2: Accidents visualisation techniques

WEB SERVICE	FEATURE USED	SHAPE	SIZE	COLOUR HUE DIFFERENCES	COLOUR VALUE DIFFERENCES	COLOUR INTENSITY DIFFERENCES
CycleStreets	**Points**	Round markers	Quantitative differences: accidents frequency	Qualitative: accidents severity	Not used	Not used
CrashMap	**Points**	Rectangular markers with accidents values	Not used	Qualitative: accidents severity	Not used	Not used
Osbornes Solicitors LLP	**Points**	Round markers with values at small scale, rectangular markers at large scale	Not used	Quantitative at small scale: frequency. Qualitative at large scale: severity	Not used	Not used
CityBeast	**Points**	Drop shaped markers	Not used	Qualitative accidents severity	Not used	Not used
DfT Accident Map	**Points**	Round markers with values at small scale, drop shaped markers at large scale	Not used	Quantitative at small scale: frequency. Qualitative at large scale: severity	Not used	Not used
BBC News UK	**Points**	Round markers	Not used	Not used	Not used	Not used

3. Data description

The central core upon which our research is built are the data, City of Edinburgh's accidents reports were extracted from the UK Road Safety Data dataset http://data.gov.uk/dataset/road-accidents-safety-data. Accidents are reported by the Police and the methodology used to collect and transmit information to the DfT is consistent across the country and is called STATS19, the system was adopted in 1979. Data consist of information regarding the accident and its attendant circumstances, vehicles involved and resulting casualties.

These three elements come as separate records, accidents record include their spatial location both in British National Grid and WGS84 coordinates, data are collected by Police forces using GPS devices and according to Anderson (2009) their error is $\pm$ 10 metres. Information about vehicles describes type (bicycle, car, van) and manoeuvre immediately before the event. Information about casualties indicates severity and if the casualty is a cyclist, pedestrian or driver.

One of the main statistical issues regarding the use of this source of data is under reporting, as well as pointed out by DfT (2013) and specifically for cycling accidents by Stone and Broughton (2003). The main reasons of under reporting are the legal non-obligation to report the accident to the Police even if it caused a casualty, the omission of accident report from the Police and the Police officer degree of subjectivity to determine whether there can be a casualty or not, as many health consequences due to an accident can occur even several days after the event. Casualties under reporting tendency is made evident by the comparison between accidents and hospital admissions; acknowledged that our data source is affected by these issues we can still say that to date STAT19 dataset is the most complete, detailed and reliable source of information regarding cycling road accidents in the UK (DfT, 2013).

4. Methodology

4.1 Data processing

Road safety data are made available through the DfT website in csv format, as we wanted to use them with a Relational Database Management System (RDMS) we first needed to structure our database, its relations (see Cristofori, 2014), creating the tables with their appropriate data type (see Appendix I) and finally load the data, we decided to use PostGIS 9.3 database system, because it performs on spatial data almost as well as Oracle (Arbesser – Rastburg, 2009) but it has the advantage to be an open source software, thus can be easily integrated with other GIS open source tools. Once data were loaded we created the geometry column using provided coordinates as spatial reference (one table for OSGB and one table for WGS84) and we filtered the entire dataset just for Edinburgh's city area and for cycling accidents. As data definitions provided with STATS19 all consisted of numerical codes, we created a definition table for each attribute to translate codes (see Appendix II) into text and finally create a view containing for each accident unique identifier all the relevant information about vehicles and casualties involved, using textual definition instead of numerical attributes (see Appendix I).

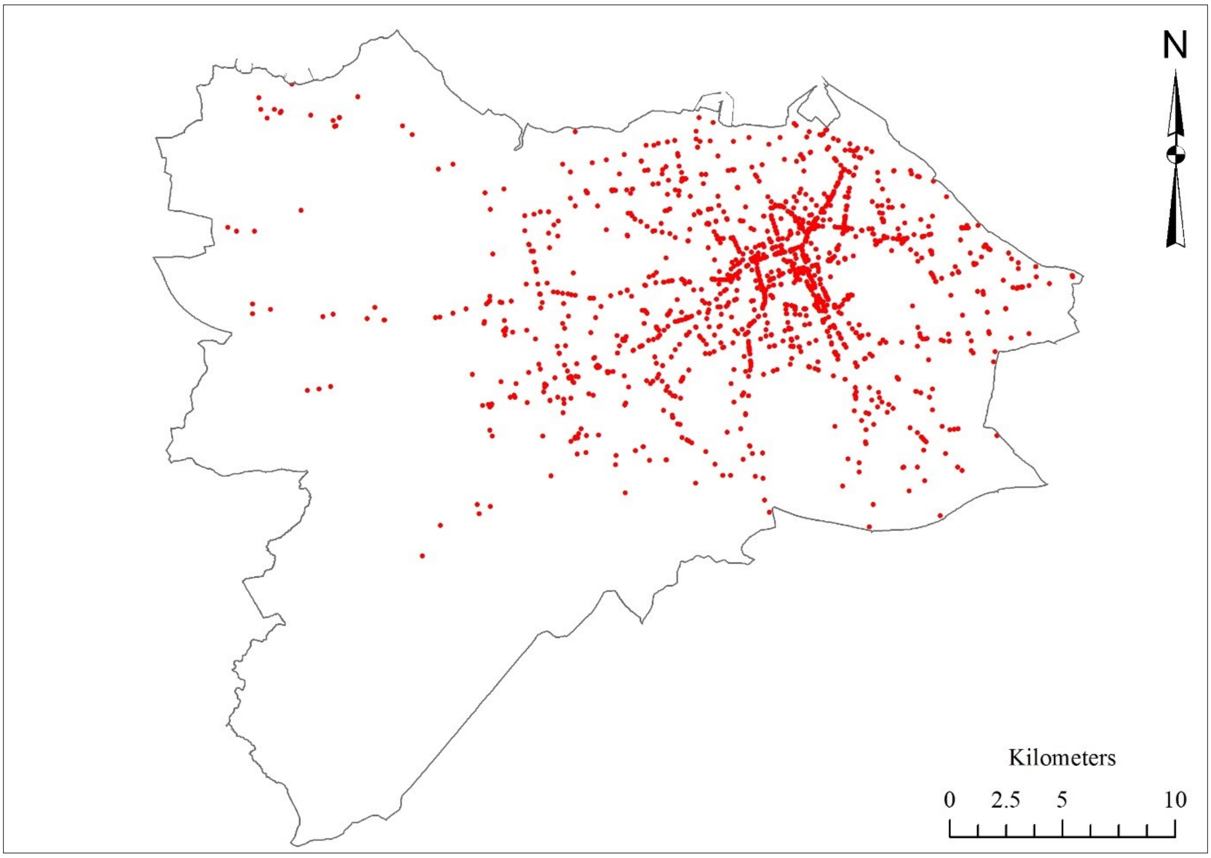


Figure 5: Point map of the distribution of cycling accidents in Edinburgh, 2005/2012

Table 3: Yearly cycling accidents summary with relative casualties. *Cyclist casualties only, source: DfT

YEAR	ACCIDENTS	NUMBER OF CASUALTIES*	SLIGHT	SERIOUS	FATAL
2005	202	195	163	32	0
2006	245	238	203	34	1
2007	204	197	160	37	0
2008	209	205	170	33	2
2009	237	234	195	38	1
2010	251	246	211	34	1
2011	268	264	227	35	2
2012	286	278	226	50	2
TOTAL	1902	1857	1555	293	9

Table 4: Yearly cycling accidents summary with relative vehicle, source: DfT
*Include the record “other vehicles”, **Include only bicycle/bicycle and bicycle/pedestrian collisions, accidents with multiple vehicles in which pedestrians and cyclists were involved are not considered in this table

YEAR	VEHICLES UNDER 3.5 TONNES*	VEHICLES OVER 3.5 TONNES	MOTORCYCLES	BICYCLES **	PEDESTRIANS **	AGRICULTURAL VEHICLES
2005	175	12	2	2	7	0
2006	220	10	0	3	7	0
2007	186	8	0	0	4	0
2008	191	5	1	4	3	0
2009	211	14	2	1	4	1
2010	218	11	4	3	7	0
2011	243	14	2	0	6	0
2012	251	13	1	3	13	0
TOTAL	1695	87	12	16	51	1

4.2 Elaboration of the cyclist preference model

The survey was conducted interviewing 38 people, suggesting different visualisation options; Results highlighted the need to elaborate a web service showing location of the most dangerous areas together with a route planner able to account for them, (see figure 6), for a detailed survey overview see Cristofori (2014) and for survey questions see Appendix IX.

The preference model foundation for the route planner will consider two criteria, safety and travel distance. As for safety, we have evidence that this is a considered criterion in the choice of a cycling route (Hopkinson and Wardman, 1996). Also distance has shown to be a considered criterion, in some studies was compared to distance and time (Howard and Burns, 2001) as cited by Ehrgott et al. (2012), authors came to the conclusion that cyclists route choice is not just based on one criterion at time but more on a combination of three. In this model, distance criterion is based on the road length segment, as recorded in the geometry attributes of OSM road network while safety is described as a combination of risk factors. STATS19 offers a wide range of information regarding risks that needed to be synthesised; pertinent literature was used to operate this selection.

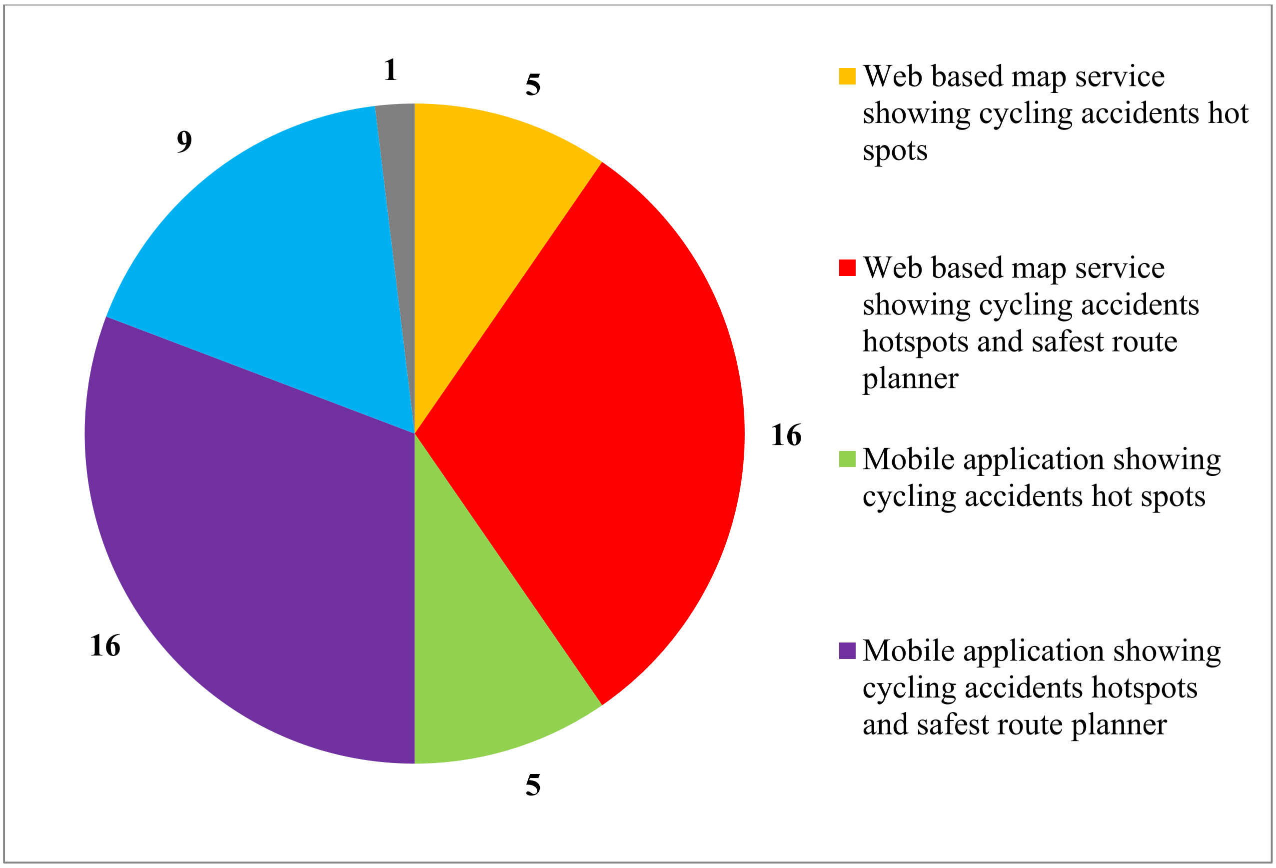


Figure 6: Pie chart showing survey results showing potential users' preference among suggested alternatives for different visualisation options

4.2.1 Risk factors identification

As observed by Lord and Mannering (2010) crash-frequency only models have a large number of limitations, one of them is the over or under dispersion of events that might lead to incorrect inferences, for these limitations we considered other risk factors. The choice was made according to past research on cycling risks; Schepers et al. (2014) regarded road users, vehicle and infrastructure as the '*three traffic safety pillars*'. An extensive literature review is provided by Reynolds et al. (2009) for infrastructures. Moreover, regarding bicycle manoeuvre, type of intersection, accidents severity and vehicles involved, according to Pai (2011), Kim et al. (2007) and Harris et al. (2013) all these can be considered factors contributing to the level of risk and severity of a cycling accident.

4.2.2 Risk factors ranking and quantification

Once identified our risks factors we ranked different degrees of risk associated to each, always on the basis of scientific evidence, when possible. Where literature sources were judged as not completely suitable for our case, we resorted to some assumptions inferred both from scientific findings and from data analysis results.

Infrastructure, data source OSM road network.

To determine the degree of risk we evaluated the road classification in OSM data. It is worth to highlight a general lack of scientific research in the UK about this topic; many examples come from the US, Canada, Belgium and Netherlands. From what was found in Reynolds (2009) and Teschke et al. (2012) risks are proportional to road rank, major streets more risky than minor, followed by local and residential streets. We ranked our road associated risk according to these criteria and the least risk score was assigned to cycle paths; this can be considered controversial to studies in Aultmann-Hall et al. (1999) and Reynolds (2009) , but there are also opposite evidences, testifying a significant contribute to risk reduction of separated cycling facilities (Teschke et al., 2012).

Bicycle manoeuvre, data source STATS19.

Pai (2011) used our same data source to assess the accidents risk in three types of bicycle manoeuvre. He noticed a series of unobserved variables contributing to the accident outcome which information is not always available. Moreover, in order to understand fully how manoeuvre is related to risk it is necessary to have a clear idea of each accident dynamic with available data, for example the location and the manoeuvre of each vehicle involved. Because of the mentioned issues we just considered bicycle manoeuvres, ranking them according to their absolute number and their outcomes severity (see Appendix V).

Type of intersection, data source STATS19.

As for simple intersections, Harris et al. (2013) in Toronto and Vancouver noticed major risk of collision between bicycles and motorised vehicles at non-intersection level, and especially between major roads; roundabouts were more risky than simple intersections. In Europe findings suggest that the risk related to roundabouts varies across countries and intersection geometry, (Shoon and Van Minnen, 1994; Daniels, 2008; Daniels, 2009). When evaluating accidents frequency at intersections in Edinburgh it is evident the role of simple intersections, T junctions and crossroads especially, in increasing cycling risk, followed by non-intersection and then roundabouts, we ranked the intersection risk accordingly (see Appendix V).

Accidents frequency and casualty severity related to accidents, data source STATS 19.

In the overall vision of this dissertation project to provide a tool to reduce cycling accidents risks and increase cyclists' safety, we assumed accidents frequency to be proportionally related to accidents risk. Cyclists' casualties consequences were considered likewise; we assumed serious, generally fractures, large entity cuts and internal damages to be more risky than those defined slight, usually those which have just minor cuts and bruises, and less risky than those defined fatal, in which the cyclist died not later than thirty days as a consequence of the accident. The same approach was also used to determine a safety bicycle model in Allen-Mulley and Daniel (2006).

Vehicles involved in the accident, data source STATS 19.

We considered bicycle collisions both with motor-vehicles, with other bicycles and pedestrians but just those cases in which at least one casualty was a cyclist. According to Kim et al. (2007) and McCarthy and Gilbert (1996), two main factors contributing to risk and accidents severity are the speed and mass of the colliding vehicle. Assuming that accidents risk dynamics followed these findings, we ranked the vehicular risk considering the vehicle mass in first instance and then the vehicle average speed. Moreover, major risk was attributed to accidents in which more than one motor-vehicle was involved, again considering vehicles masses.

Once our risks factors were ranked we quantified related risk on a score scale varying from 1 to 10, where 1 represents the least suitable choice for a segment in a potential cycling travel from A to B, thus the most risky and 10 the most suitable hence the less risky (ESRI, 2013).

4.2.3 Accidents dataset risk scores assignment

Single scores to each risk factor occurrence were given with two methods on the basis of scores ranging from 1 to 9, as 0 would have eventually resulted in no modification of road final cost and 10 means no accident. An example of the first method can be found in vehicles involved; we compared all occurrences and evaluated their risk considering both the severity outcome and model principles. In our data, multiple vehicles accidents showed more severe outcomes than single vehicle, thus we distributed the risk according to number and vehicle mass. In the second method we divided the available scores for risk occurrences and distributed the risk uniformly. For examples in the case of manoeuvre (see table 7), occurrences are 18 then 10/18 = 0.5, the least score is 0.5 and as suitability grows, always considering our model and data evidences, each occurrence score is increased of 0.5 until reaching 10, which again means no accident. All risk factors consisted of attributes contained in the accidents dataset a part from one, the road classification; we started working on the former. The crash-frequency at same x and y coordinates was obtained using the ArcGIS collect events tool. In these cases counted risks factors were assigned on the basis of the worst accident scenario that took place in the course of the studied time period. All scores for each accident were summed, obtaining a total suitability score varying from 4 to 30 (see figure 7). The accidents dataset was subsequently loaded in PostGIS with the pgShapeLoader utility.

Table 5: Suitability scores for road classification

TYPE OF INFRASTRUCTURE	SUITABILITY SCORE
PRIMARY ROAD	1
SECONDARY ROAD	2
TERTIARY ROAD	3
ROADS	4
UNCLASSIFIED	5
RESIDENTIAL	6
SERVICE	7
LIVING STREET	8
PEDESTRIAN	9
TRACK	9
FOOTWAYS	9
PATHS	10
CYCLE WAYS	10

Table 6: Suitability scores for type of intersection

TYPE OF INTERSECTION	SUITABILITY SCORE
T OR STAGGERED JUNCTION	1
NOT AT JUNCTION OR WITHIN 20 METRES	2
CROSSROADS	3
ROUNDABOUT	4
OTHER JUNCTION	5
MORE THAN 4 ARMS	6
MINI-ROUNDABOUT	7
PRIVATE DRIVE ENTRANCE	8
SLIP ROAD	9
NO ACCIDENT	10

Table 7: Suitability scores for crash-frequency

NUMBER OF ACCIDENTS PER ROAD SEGMENT	SUITABILITY SCORE
10	0.90
9	1.80
8	2.70
7	3.60
6	4.50
5	5.40
4	6.30
3	7.20
2	8.10
1	9.00
0	10

Table 8: Suitability scores for bicycle manoeuvre

TYPE OF MANOEUVRE	SUITABILITY SCORE
GOING AHEAD OTHER	0.50
TURNING RIGHT	1
OVERTAKING STATIC VEHICLE OFFSIDE	1.50
MOVING OFF	2
SLOWING OR STOPPING	2.50
TURNING LEFT	3
OVERTAKING - NEARSIDE	3.50
GOING AHEAD RIGHT-HAND BEND	4
WAITING TO GO - HELD UP	4.50
CHANGING LANE TO RIGHT	5
GOING AHEAD LEFT-HAND BEND	5.50
OVERTAKING MOVING VEHICLE - OFFSIDE	6
REVERSING	6.50
WAITING TO TURN RIGHT	7
U-TURN	7.50
DATA MISSING OR OUT OF RANGE	8
PARKED	8.50
WAITING TO TURN LEFT	9
NO ACCIDENT	10

Table 9: Suitability for vehicle involved in the accident

MORE THAN 1 MOTOR VEHICLE INVOLVED	**SUITABILITY SCORE**
CAR AND COACH	1
CAR AND GOODS 7.5 TONNES MGW AND OVER	1
COACH AND VAN/GOOD 3.5 TONNES OR UNDER	1
MULTIPLE COACHES	1
CAR AND GOODS OVER 3.5T AND UNDER 7.5T	1.5
CAR AND TAXI	2
CAR AND VAN /GOOD 3.5 TONNES AND UNDER	2
MULTIPLE CARS	2
1 MOTOR VEHICLE INVOLVED	**SUITABILITY SCORE**
BUS OR COACH	3
GOODS 7.5 TONNES MGW AND OVER	3
GOODS OVER 3.5T AND UNDER 7.5T	4
MINIBUS	4
VAN /GOOD 3.5 TONNES OR UNDER	4.5
CAR	5
OTHER VEHICLE	5
TAXI/PRIVATE CAR	5
MOTORCYCLE OVER 500CC	5.5
MOTORCYCLE OVER 125 UP TO 500CC	6
MOTORCYCLE 125 AND UNDER	7
AGRICULTURAL VEHICLE	8
MOTORCYCLE 50 AND UNDER	8
NO MOTORISED VEHICLE INVOLVED	**SUITABILITY SCORE**
BYCICLE	9
PEDESTRIAN	9
NO ACCIDENT	10

Table 10: Suitability score for casualty severity

CYCLSIT CASUALTY SEVERITY	**SUITABILITY SCORE**
FATAL	1
SERIOUS	4
SLIGHT	7
NO CASUALTY/NO ACCIDENT	10

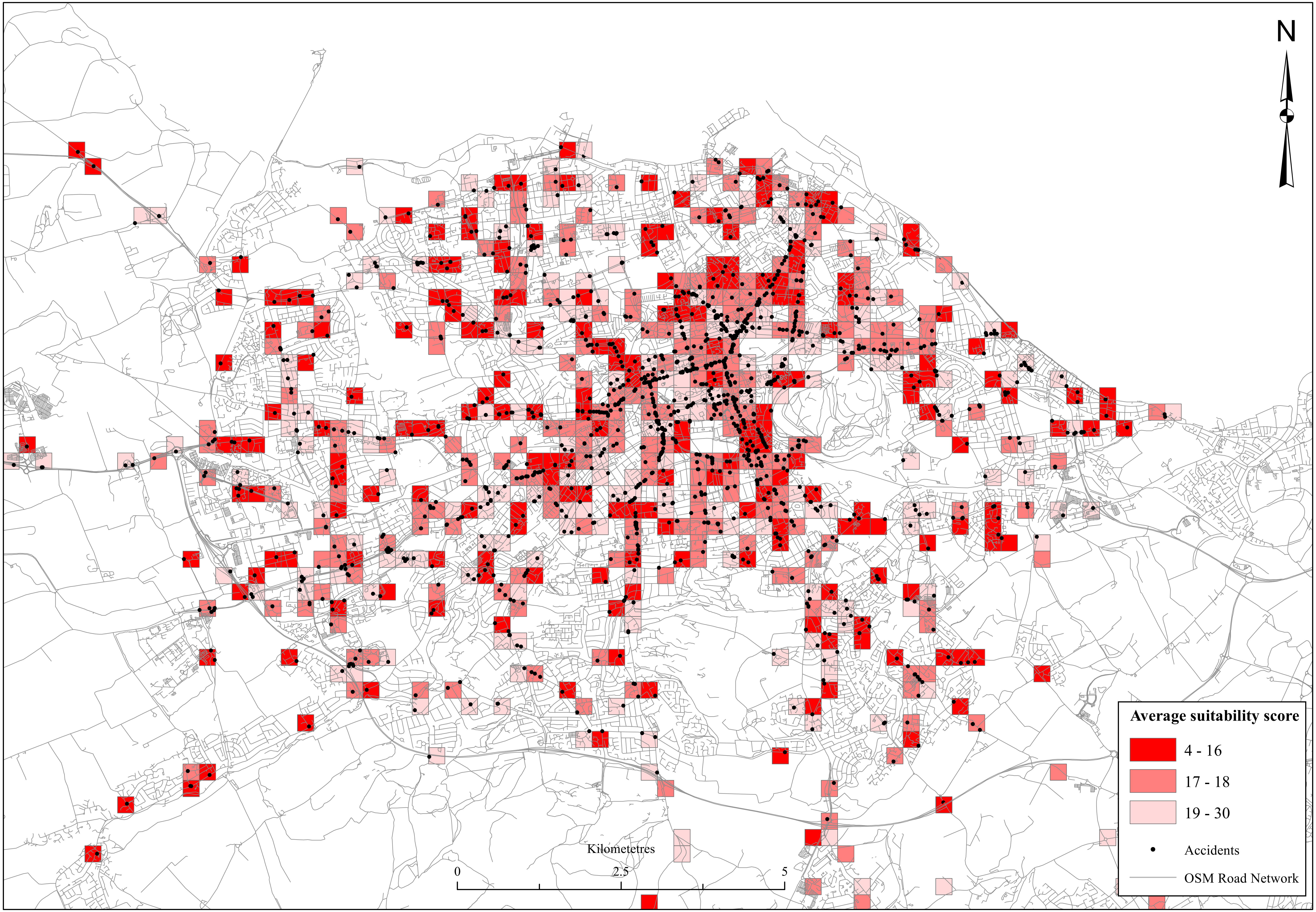


Figure 7:Representation of average accidents suitability score within a 250 metre grid

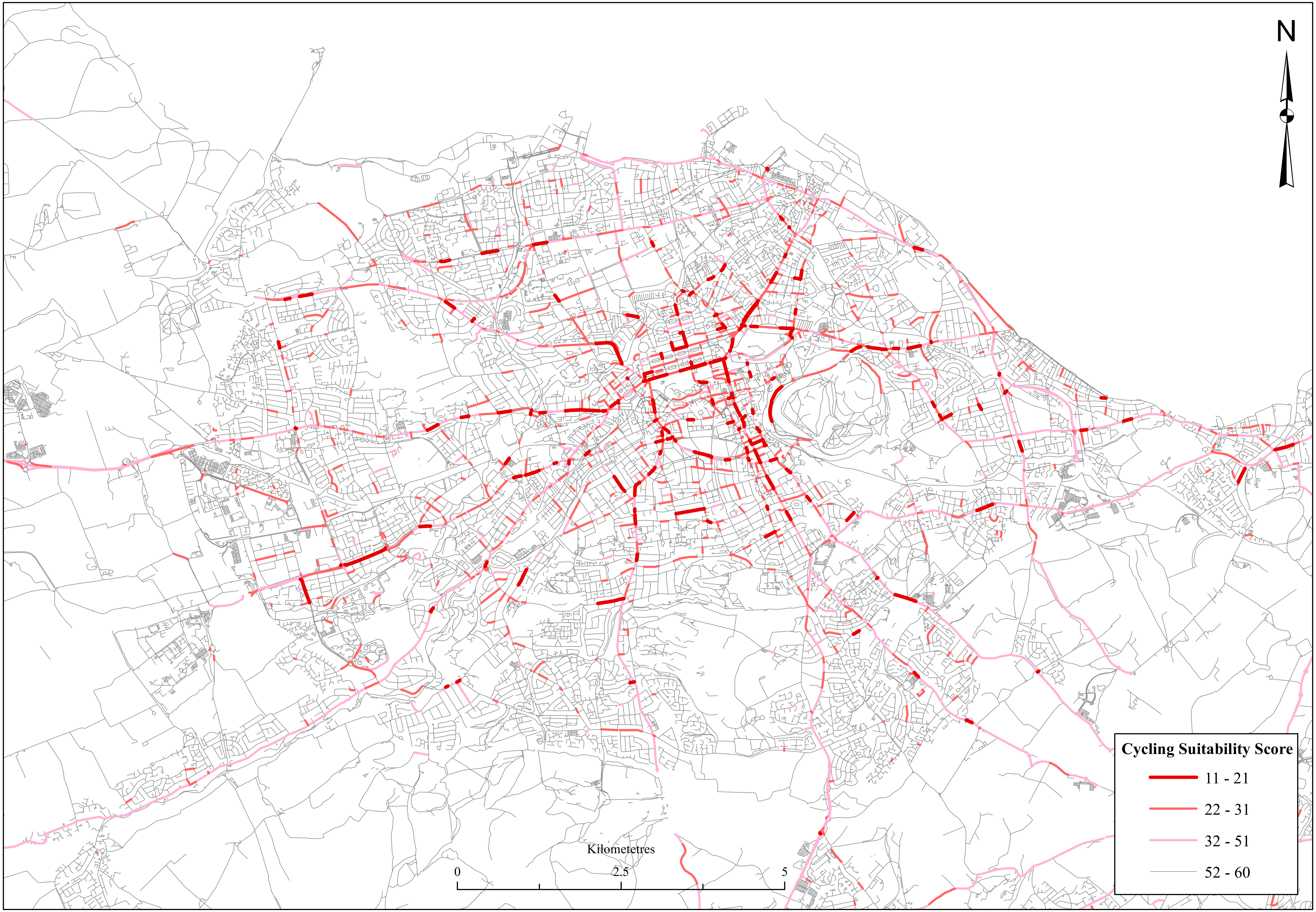


Figure 8:Representation of roads accidents total suitability score on OSM road network

4.3 Elaboration of the safety web-based routing planner

The road network (including cycle paths) used in our route application, comes from OpenStreetMap (OSM). Mondzech and Sester (2011) found OSM to be more accurate than other non-crowd sourced maps, especially regarding urban paths and particularly in denser urban areas. According to CycleStreets UK Edinburgh's cycling paths and facilities are "*pretty well mapped*" although it is possible to find some inaccuracies. OSM data can be used and published without any licence restriction, we considered this characteristic an optimal trade-off for minimal inaccuracies.

4.3.1 Data processing

Data were downloaded from https://mapzen.com/metro-extracts/, a web service that offers OSM maps extracts for most world cities automatically updated each week. Source data were initially in "Protocol buffer Binary Format", a highly compressed low-level data descriptive language that allows the storage of large amounts of information in relatively small files, compared to XML. OSM data are already topologically structured but they do not contain any topological description, fundamental feature for a routable network. To make our network routable we used the osm2po 4.8.8, a java utility that parses pbf files and builds topological consistent graphs out of it. Other important characteristic of osm2po 4.8.8 is its configuration file, which setting allowed us to exclude from loading roads in which cycling is not allowed such as motorways, roads reserved to motor-vehicle or only pedestrian circulation (see Appendix IV).

4.3.2 Network dataset creation

At the end of each data loading osm2po creates a sql file which can be executed in our PostGIS database to load the road network with all the attributes that are necessary to routing (see Appendix IV); besides it contains a "cost" and a "clazz" (class) fields. At loading, the former contain default values, given by the ratio between the maximum speed of the segment and its length, the latter contains a numeric tag for road classification, i.e. 15 for primary roads and 21 for secondary. Those fields, together with the reverse cost, contained the information that we needed to modify the costs of network edges and make it aware of road risks.

4.3.3 Network dataset post-processing

Once the data were loaded in our PostGIS database it was necessary to assign the risk score for each graph edge, join the network with remaining attributes contained in the accidents dataset, transforming risks scores in costs and weighting the risk criterion with the segment length. Attributes belonging to points were joined to the nearest road network segment using QGIS; we dealt with multiple accidents similarly to accidents with same x, y coordinates. This method of segment risk attribution was preferred to the detection of accidents hotspots because it allowed more flexibility in risk quantification requiring less time, a hot spot approach on the other hand would have provided a finer resolution of the distribution of different sources of risk. Finally all risks scores were summed for each edge giving us a total suitability score varying from 11 to 60 (see figure 8).

4.3.4 Distance weighting and costs assignment

When considering research regarding cycling attitudes towards distance and safety in route choice results do not always appear to be consistent; in Aultman-Hall et al. (1997) as cited by Erghott et al. (2011) observed cycled paths are more similar to shortest paths while the results of the survey of Winters et al. (2011) demonstrate that safety issues are seen as the highest deterrent to cycling while distance had a relatively important role. We decided to take into account both points of view thus considering safety be moderately more important that distance in Malczewski scale for Pairwise Comparison, weights were assigned according to the mentioned method (Malczewski, 1999 p.182). The weight assigned to distance criterion in our model was 0.25, 0.75 to safety, see Cristofori (2014) for the detailed weighting methodology.

The cost for each segment was then calculated as follows.

*COST = (segment length * 0.25) / (suitability score * 0.75)*

4.3.5 The routing algorithm

We decided to use PgRouting as routing engine because, differently from other commercial products, it easily integrates PostGIS and allows more tweaking options of routes characteristics respect to commercial router. For single starts and end points it is possible to choose between A* and Dijkstra's algorithm, we decided to use the latter for two reasons; we noticed its more use in similar research regarding cycling safety (Su et al., 2010; Singleton and Lewis, 2011; Ehrgott at al., 2012) and following a performance test on our dataset, better results were found in Dijkstra at minimising both lengths and costs, (see Cristofori, 2014). Before running the algorithm some data post processing was required, together with the cost we set roads reverse cost in order to respect turn restrictions, information on turn restrictions are those provided with the OSM dataset. The first tests on the elaboration of the routing function were done in QGIS.

4.3.6 Creation of the web-based application

Our data stored in PostGIS database were published using Geoserver. In order to handle the users' requests to the database, layers management and map function we used OpenLayers version 2.13.1, a JavaScript library which allows the display and manipulation of maps and other geographic data. Geographic data are displayed as WMS and the layers contained by the map are OpenCycle map as base, a layer containing the location of accidents represented as points with different colour for the accident severity and when the least cost path layer upon user's request. The retrieval of the least cost path is initiated by two clicks on the screen, the first for the start point and the second for the destination point. OpenLayers library gets the coordinates and sends them via the URL with a GET request to GeoServer (see Appendix VII). Coordinates as text strings are used as substitution variables in our pgRouting query that uses a built in a Procedural Language Pgsql function finding the nearest start and end node from the given coordinates (see Appendix VI). Once the least cost path is returned to the web page is stored as a view in GeoServer and displayed as a new WMS layer.

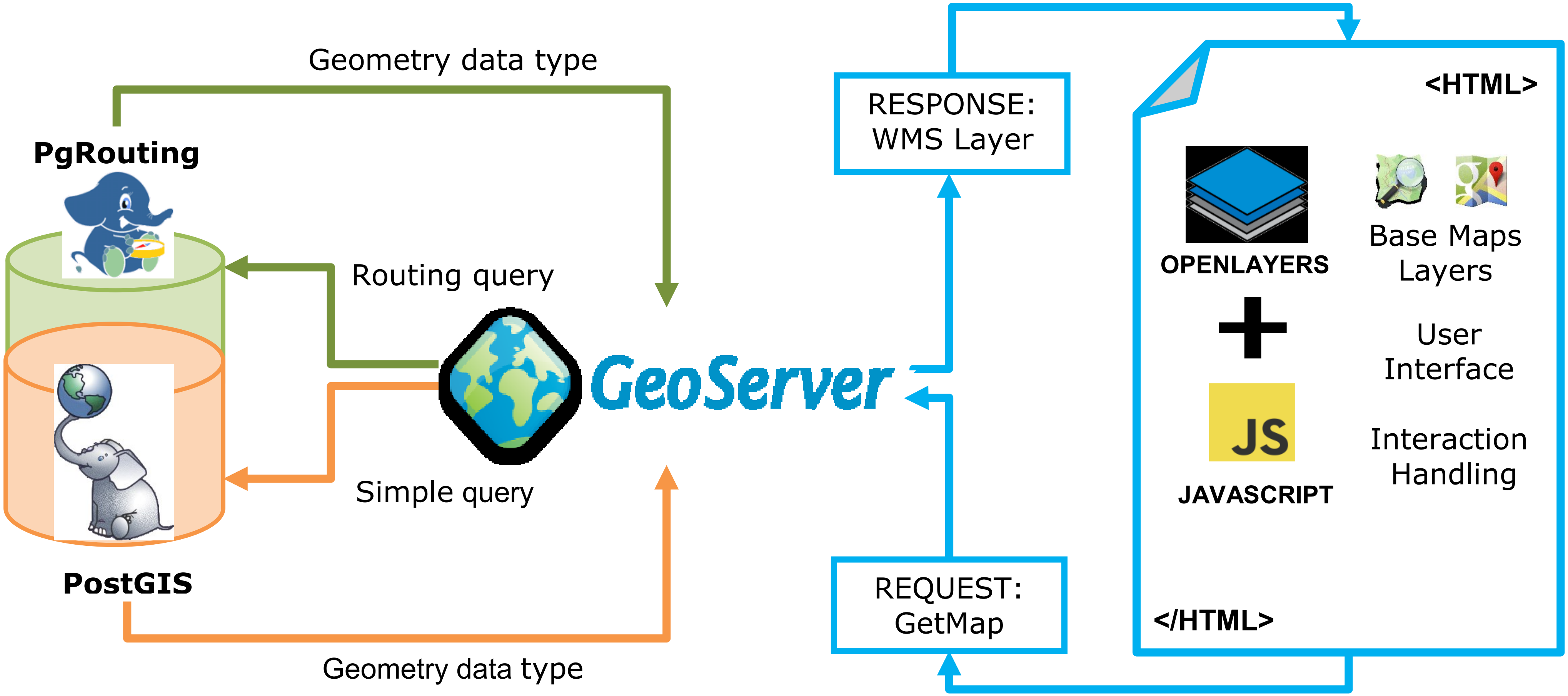


Figure 9: System diagram of the web service

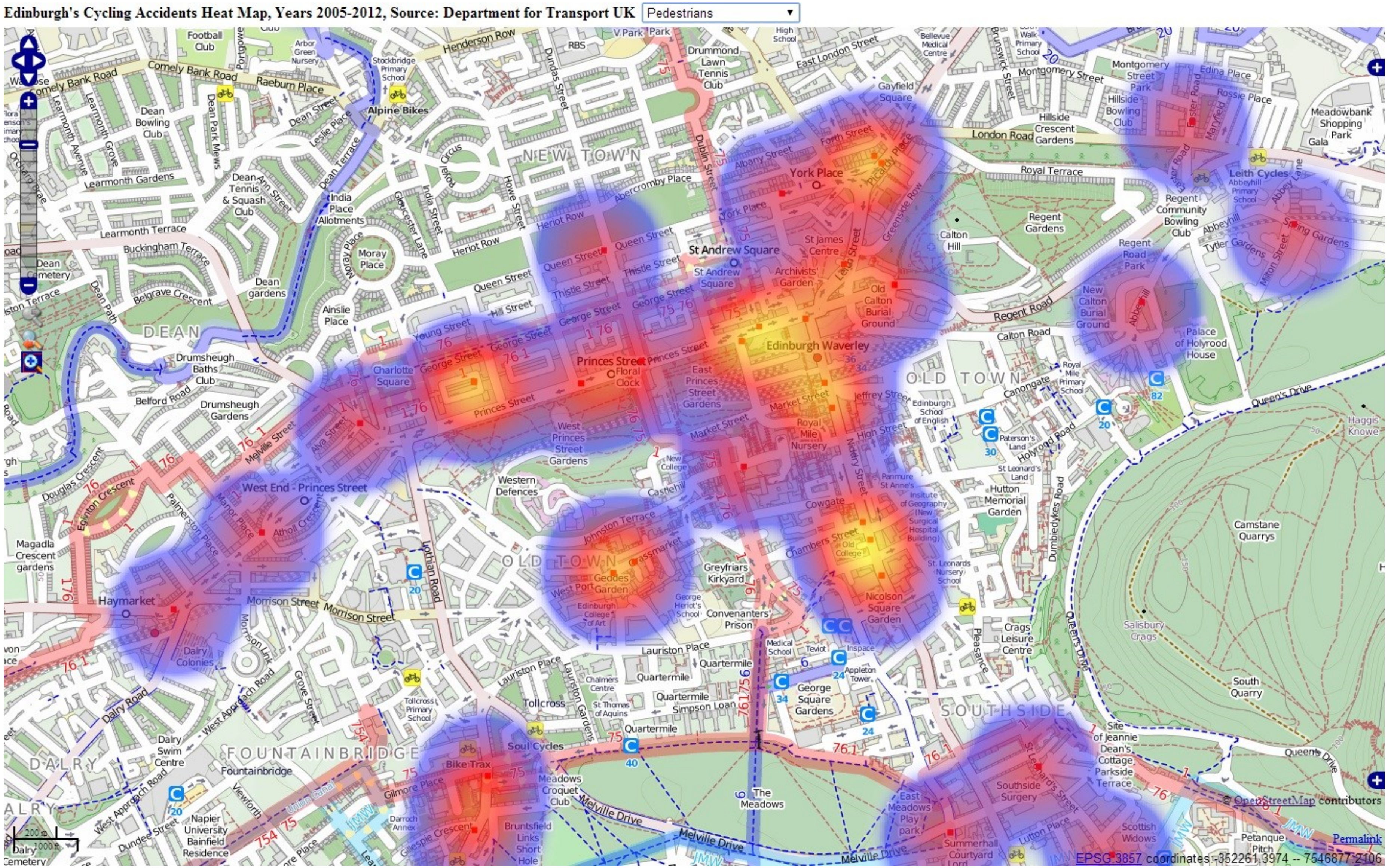


Figure 10: Screenshot of the web-service with bicycle/pedestrians accidents hotspots represented as a heatmap in Edinburgh city centre

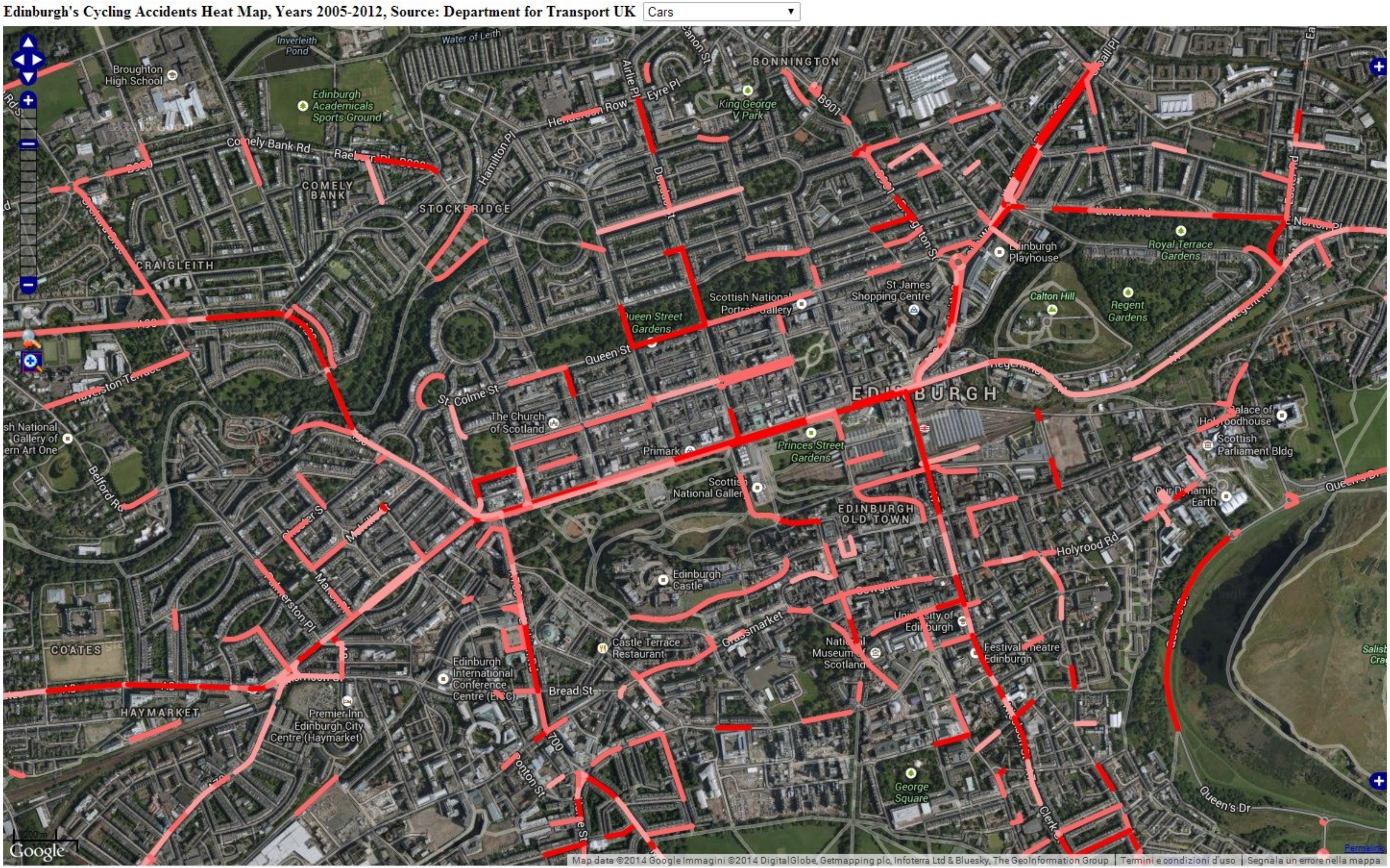


Figure 11: Screenshot of the web service showing road suitability on streets using red hues, darker tonalities indicate less suitability

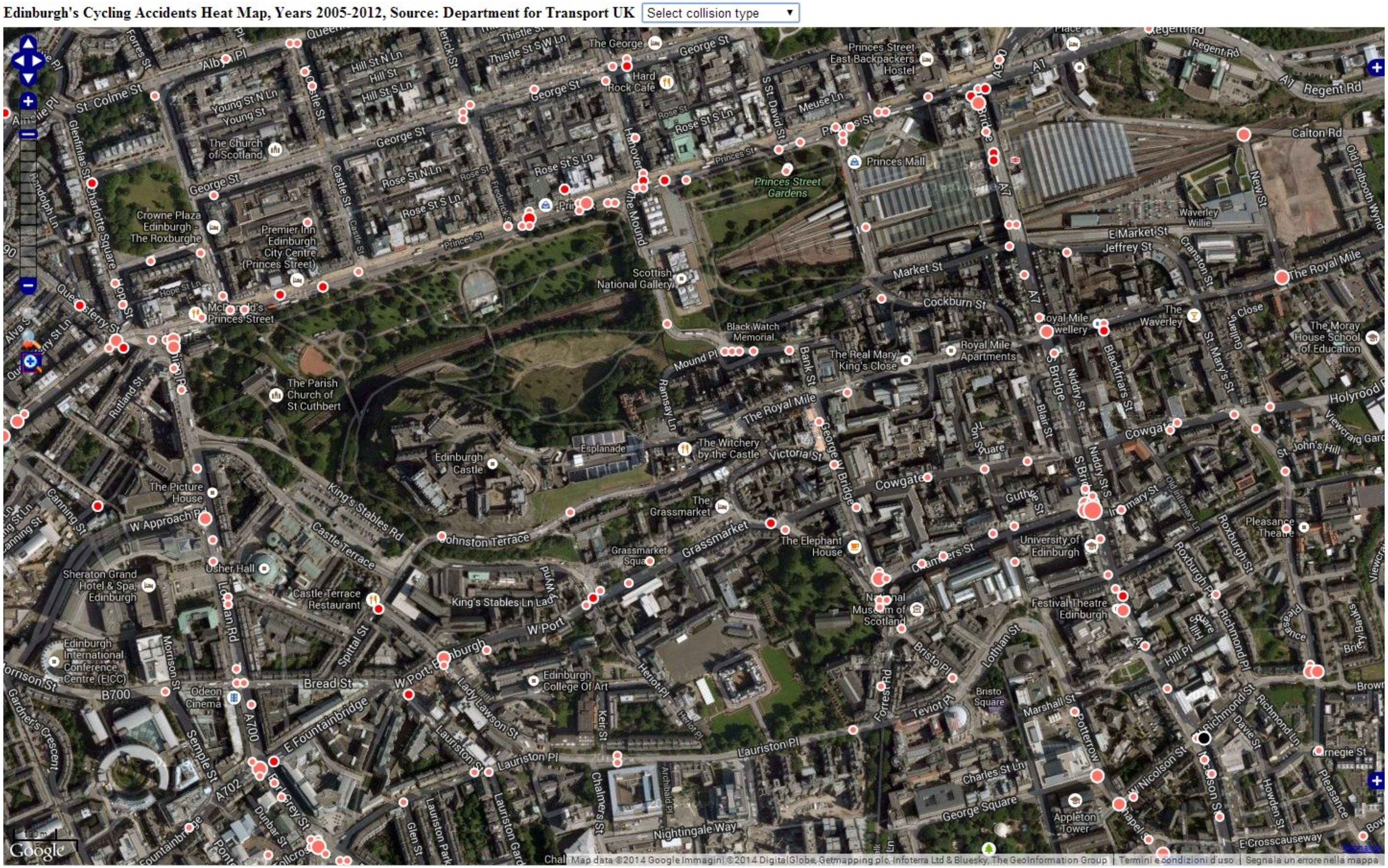


Figure 12: Screenshot of the web service showing accidents as points, hues of red for increasing severity, black for fatal; points' size is proportional to accidents frequency

4.4 Web application testing

We wanted to test:

1. How good is the model at minimising cycling risk, and how it deals with route length.

2. How effectively the project succeeds at communicating risk.

We divided the test in two parts, in the first we will compare our safest routes with others that do not include risks' factors, comparing distances and total suitability.

In the second, we will ask 20 people, divided between Edinburgh's regular and non-regular cyclists, to compare the routes suggested by our service and by Cyclestreets "quietest route". The reason for choosing two different types of potential web service users' was to assess any difference in route preference dependent on experience, as found in Broach et al. (2012).

4.4.1 Risk minimisation test results

We randomly generated 50 paths, we measured their length and suitability score per route metre, this to avoid misleading results as longer routes might appear as more suitable just because longer; similar approaches to routes testing can be found in Su et al. (2010), Ehrgott et al. (2012) and Singleton and Lewis (2011).

If we initially consider separately length and risk, in 40 out of 50 tests accidents aware routes were shorter, with an average difference of 687.27 metres, 17.8% less than those not including past collisions. As for risk, in 30 out of 50 tests accidents aware routes suitability score per metre was higher than those without accidents with an average of 0.14 per metre, 15.7% more suitable than those not including accidents as risk.

On the other side, simple routes performed better in length in 5 out of 50 tests with an average difference of 42.08 metres, 2.97% less than those with accidents. Regarding suitability, in 15 out of 50 tests routes not considering past accidents performed better, with an average difference of 0.10 per metre, 8.5% more suitable than those including accidents. In 5 out of 50 tests both algorithm had the same performances, thus the least cost path returned was the same.

If we consider both criteria together, in 26 out of 50 tests the accidents aware algorithm returned the best route (minimum length, maximum suitability), in 1 test the best route was returned by the other algorithm. Worst routes are those with the maximum length and the minimum suitability, in 26 cases this was the result of the algorithm not including accidents and in 1 case this was the result of the other.

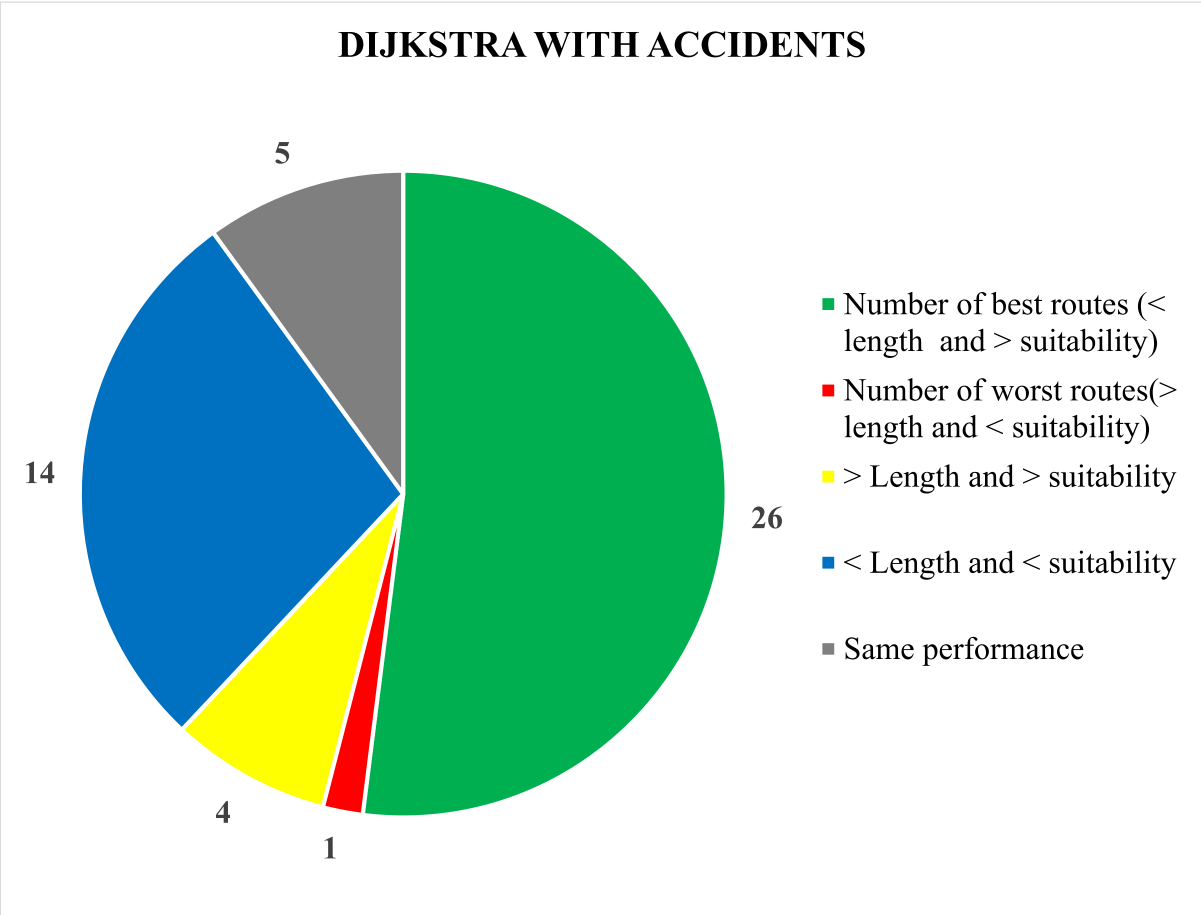


Figure 13:Pie chart showing results in the risk minimisation test for the accidents-aware algorithm

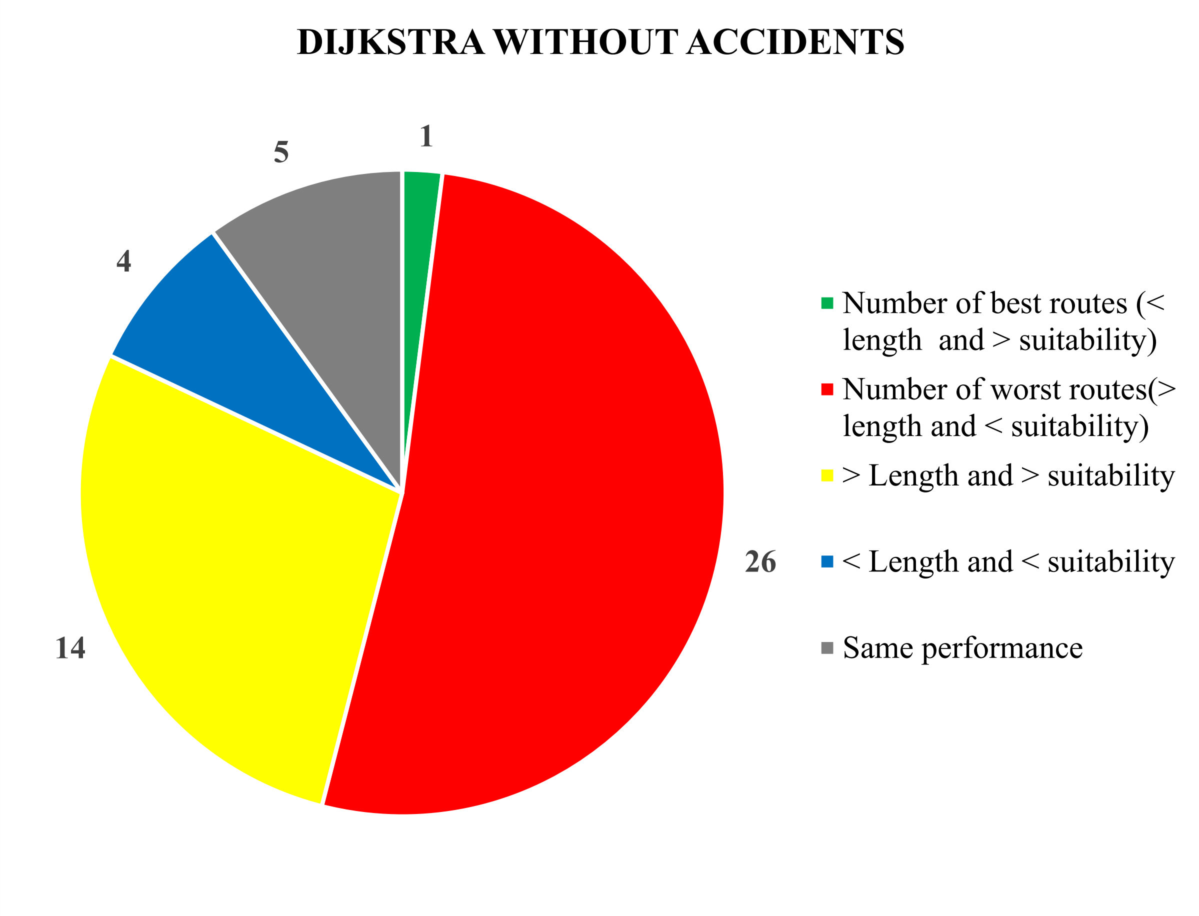


Figure 14: Pie chart showing results in the risk minimisation test for the non-accidents-aware algorithm

4.4.2 Web service effectiveness test results

On questions aimed at testing how effectively the service communicated location of accidents. All interviewed declared to be more aware of the location cycling risks, those who already knew were risks points were, all belonging to the regular cyclists group, declared that the service revealed the points they recognised as riskiest.

On questions focused on least risky routes, 6 out of 10 regular cyclists agreed about the effectiveness of the service (see figure 19) and 5 said to be ready to reconsider their ordinary route for the one suggested by the web service, 4 neither agreed nor disagreed about this question (see figure 20). Among non-regular cyclists, 8 out of 10 recognised the general web service effectiveness, one neither agreed nor disagreed and another did not agree that the route planner is good at showing safest routes. 6 respondents declared to be willing to take our suggested routes if they were to cycle in Edinburgh.

As for the comparison with CycleStreets (see figure 21), 5 regular cyclists preferred our service, 3 Cyclestreets and 2 had no preference; among non-regular cyclists 7, 2 and 1 had respectively the same preferences. Figures 15 to 18 illustrate examples of the comparison between our web-GIS and Cyclestreets.

On a question aimed at assessing the general performance of our web service, 8 regular cyclists and 9 non-regular cyclists judged our web service as good.

Moreover, respondents were asked to comment the effectiveness of the route choice model, motivating the reasons for not choosing our routes and providing a general web service evaluation.

Question n. 7:

If you answered "Strongly disagree" or "Disagree" to question 6. Could you please briefly explain why you would not consider the suggested route?

Answers by regular cyclists group:

"*Because I usually take the fastest route and even if there is high cycling risk, I am just very careful not to get hurt*."

"*It is longer and seems more complex to remember. The web service does not inform the vehicles involved in the accidents and the manoeuvre.*"

"*I use my own concept and experience of safety, therefore it will be unlikely I change my route. I prefer the fastest, which are not the safest in general*."

Answers by the non-regular cyclists group:

"*The route given by the planner is more difficult to follow. It is a bit like a labyrinth.*"

"*It is good to know where the most dangerous places are, but I prefer the fastest way.*"

"*As the focus is safety the planner does its job, still I would choose the fastest.*"

Question n. 10:

Leave any comment you think relevant to the evaluation of the web service:

"*As a person that does not cycle but I would like to, I find this service very useful because I would like to know where accidents are so to avoid them, otherwise I would be scared to cycle*."

"*I like the heat map combined with the view of the safe route together, it allows completely to see that the route avoids the hotspots.*"

"Well done, I did not know where the accidents were located before, in case I will decide to take the safest route this is a good tool."

Non - regular cyclists group - accidents aware route planner preferred to CycleStreets

Green: quietest route, red: fastest route | Green: safest route, red: quietest route

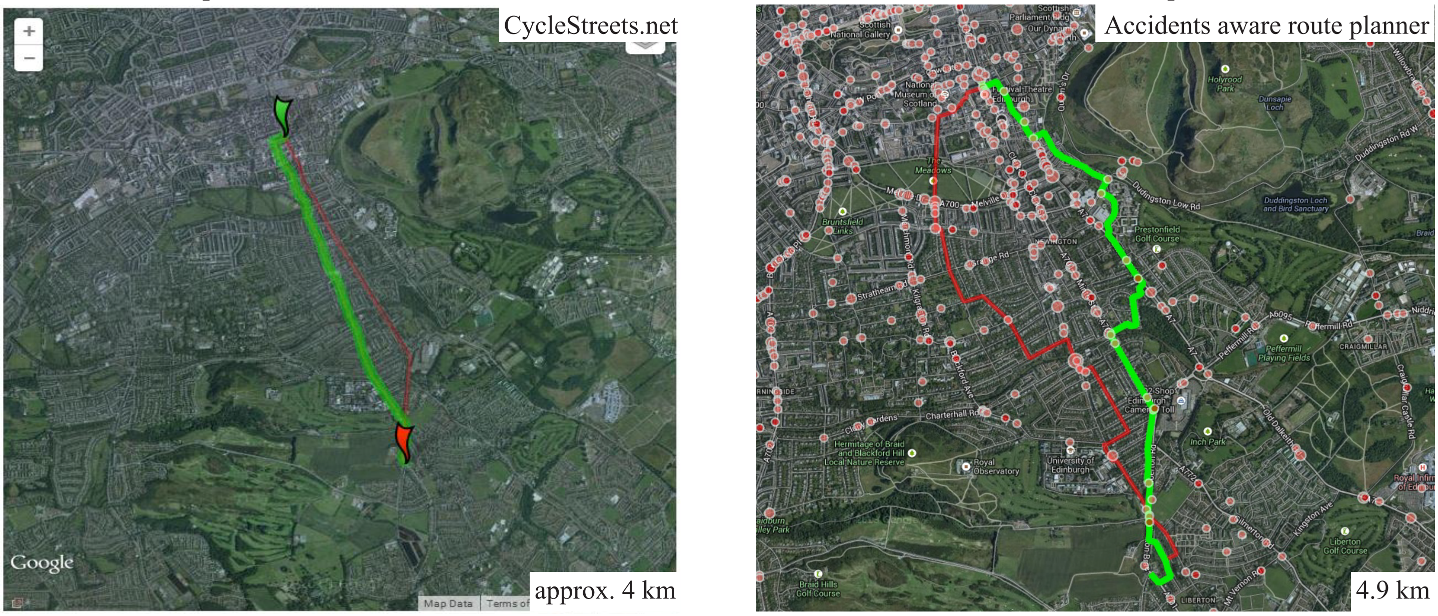


Figure 15.1:From Edinburgh's University Old College to Liberton Brae

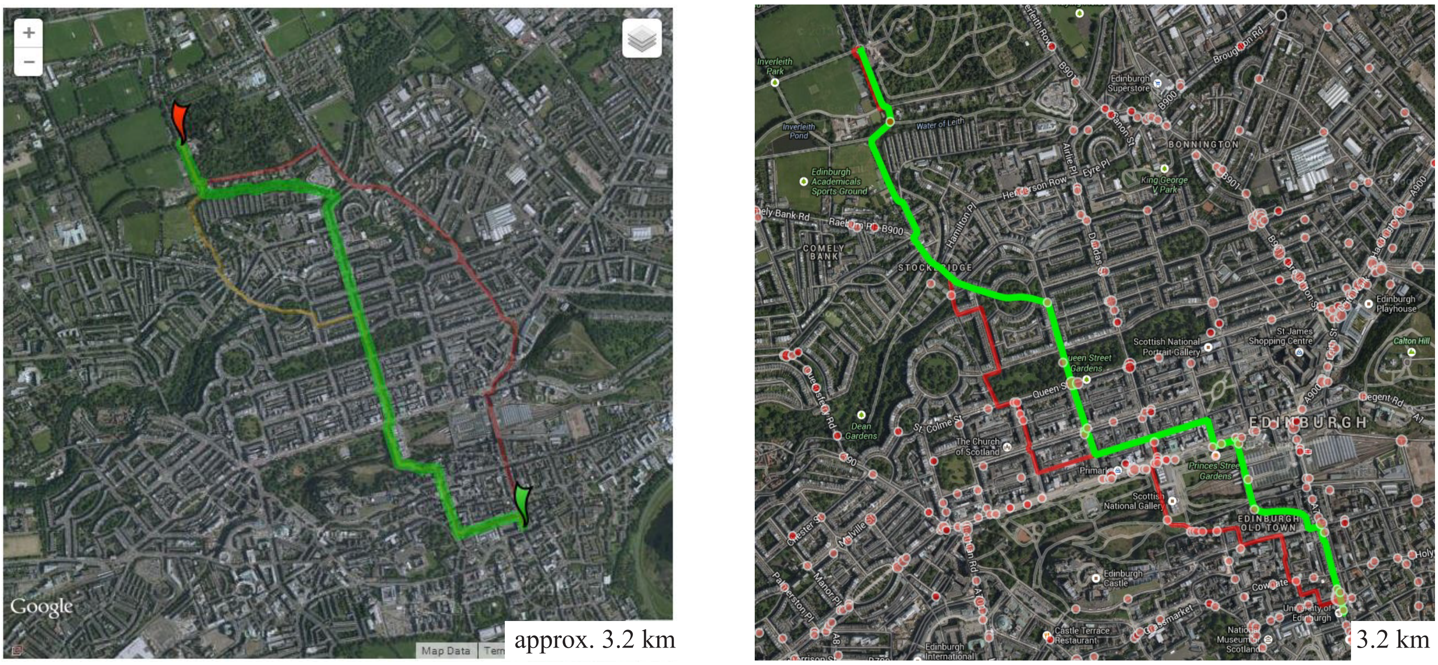


Figure 15.2:From Edinburgh's University Old College to the Botanical Gardens

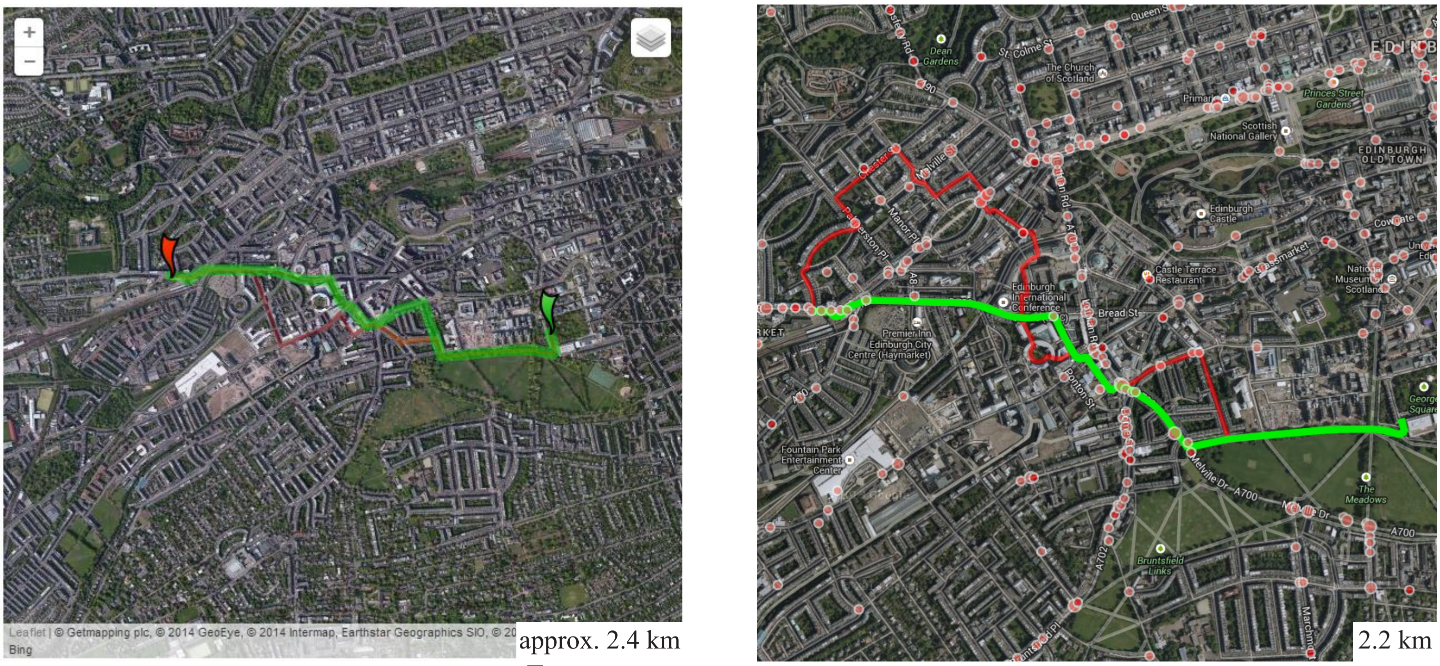


Figure 15.3:From George Square to Haymarket train Station

Non - regular cyclists group - CycleStreets preferred to accidents aware route planner

Green: quietest route, red: fastest route

Green: safest route, red: quietest route

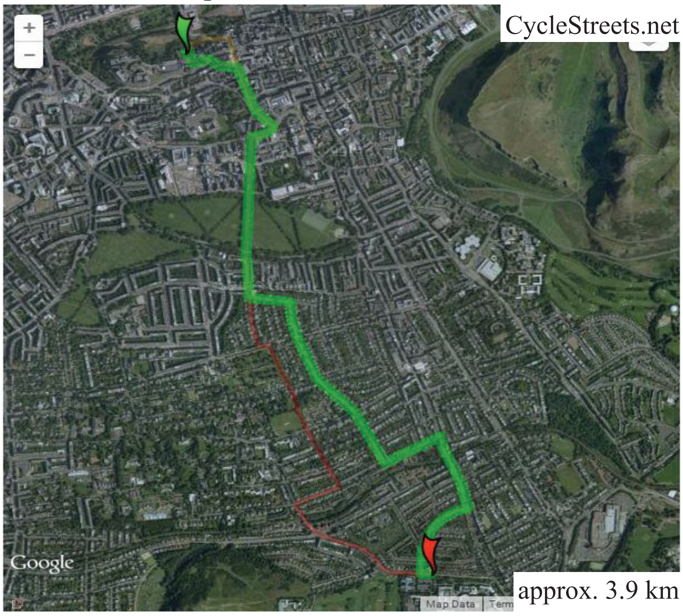
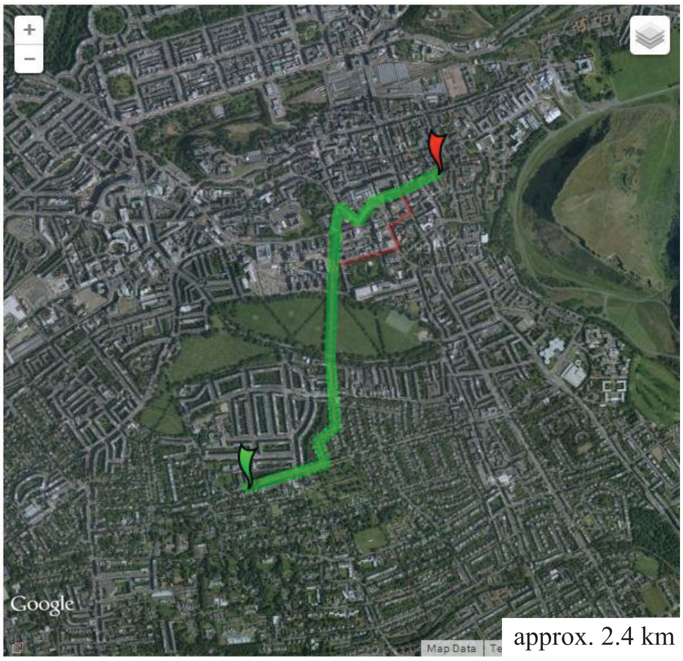


Figure 16.1:From Ramsay Garden to Kings Buildings



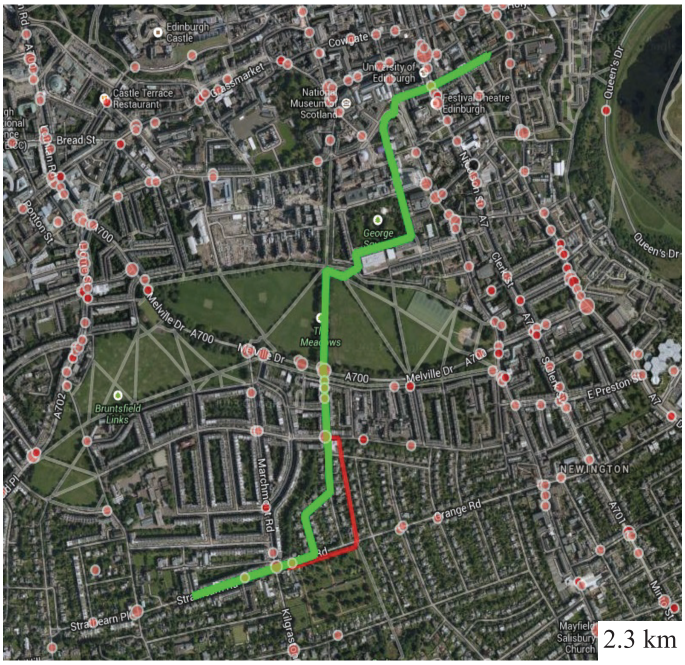
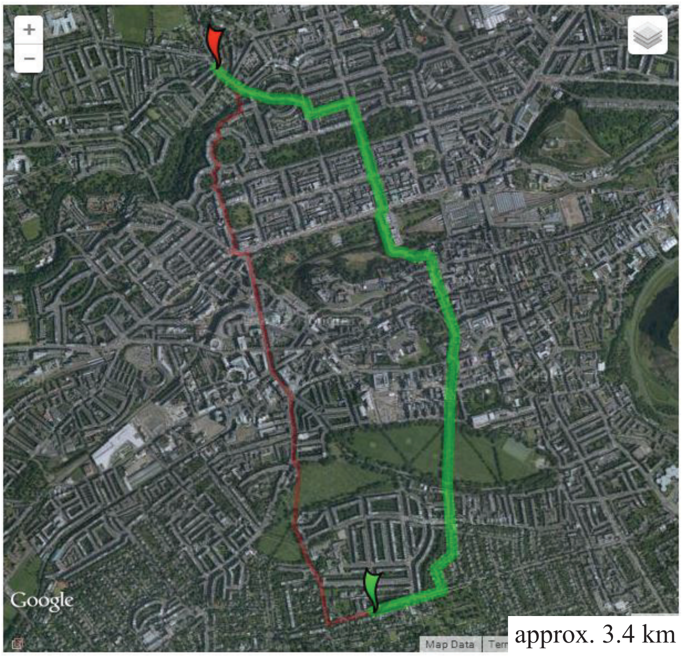


Figure 16.2:From Strathearn Road to Drummond Street



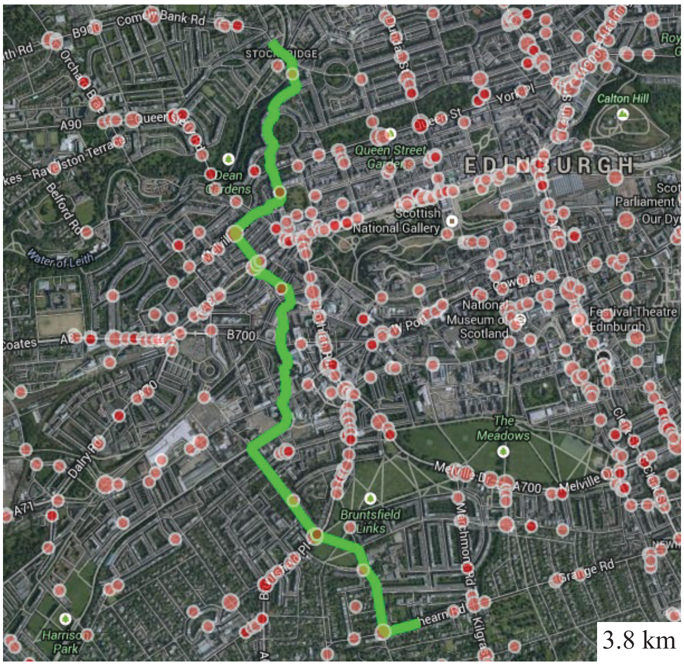
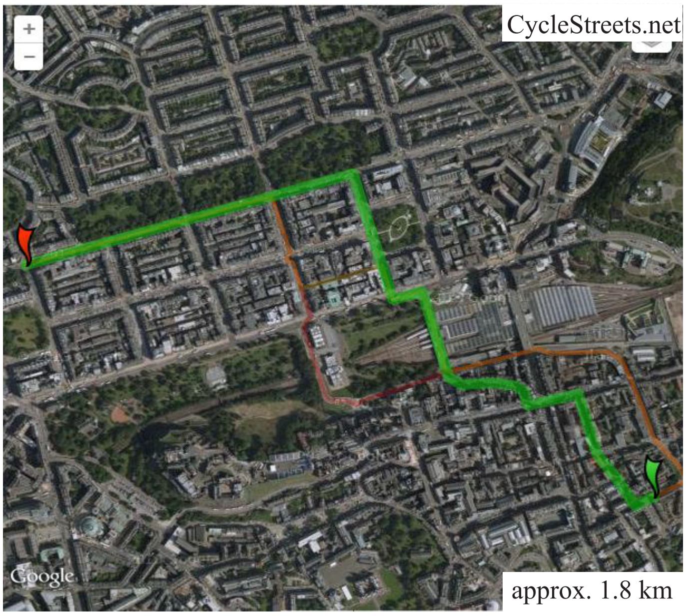


Figure 16.3:From Strthearn Road to Haugh Street

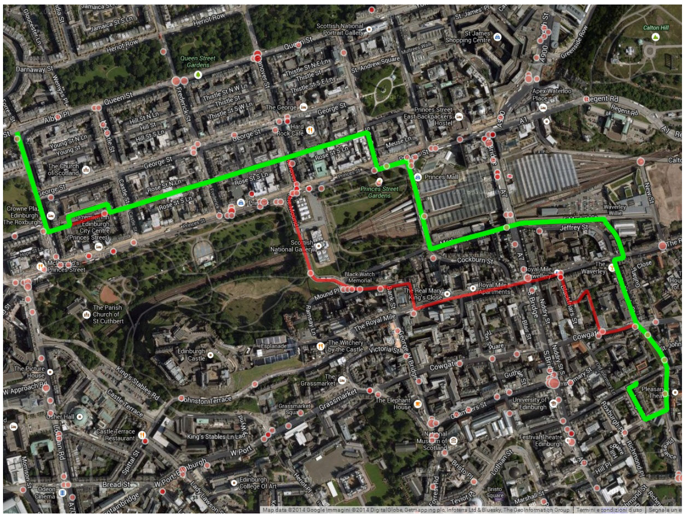
Regular cyclists group - CycleStreets preferred to accidents aware route planner

Green: quietest route, red: fastest route

Green: safest route, red: quietest route

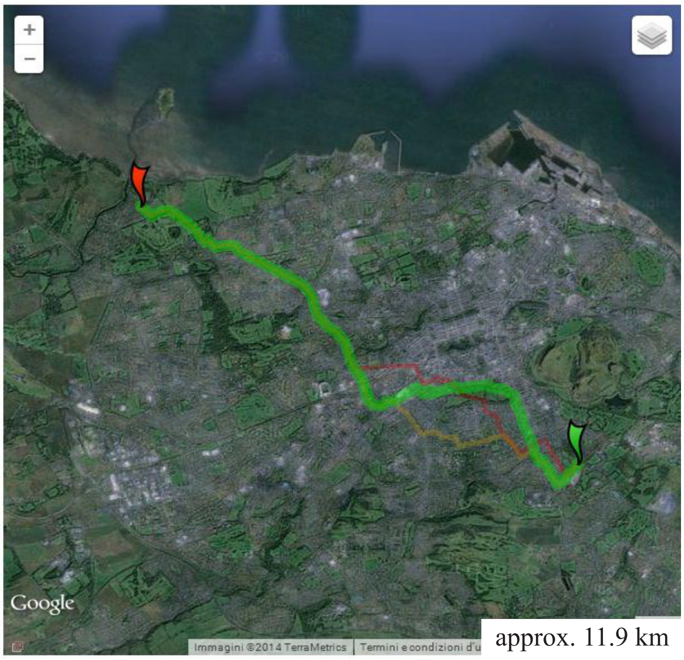


Accidents aware route planner



2.6 km

Figure 17.1:From Drummond Street to Charlotte Square



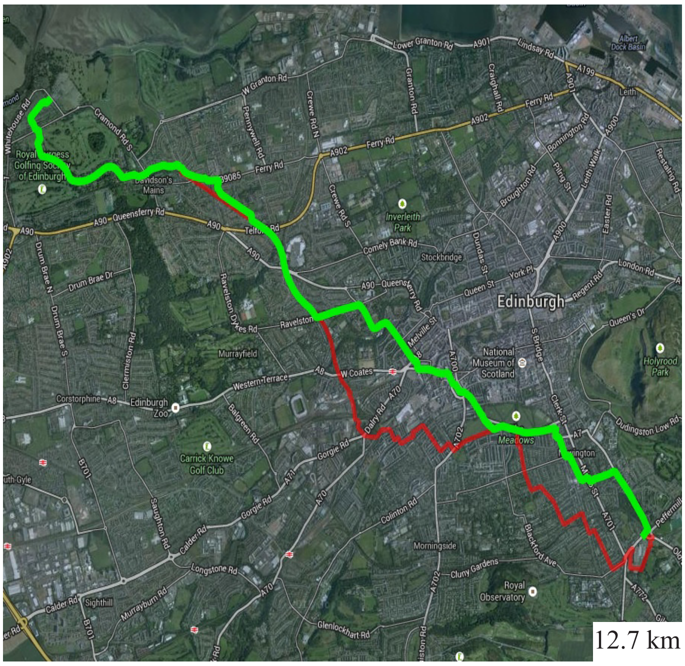
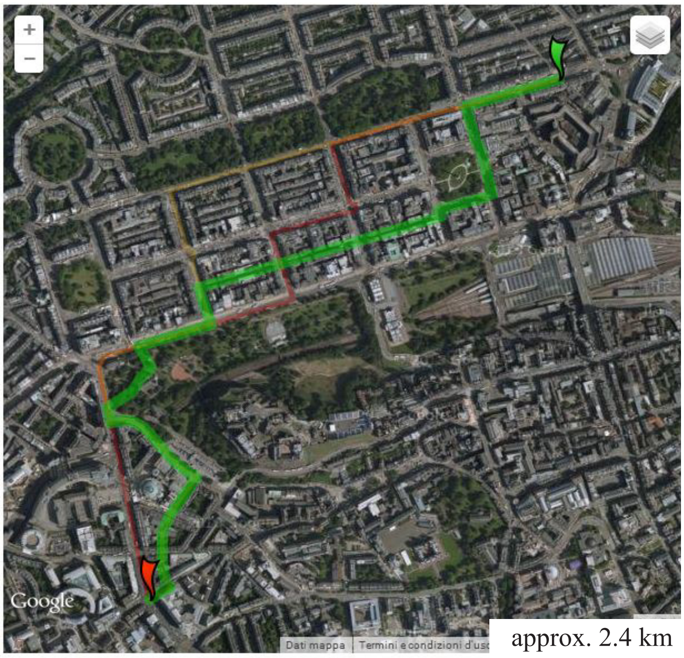


Figure 17.2:From Cameron Toll to Cramond Road North



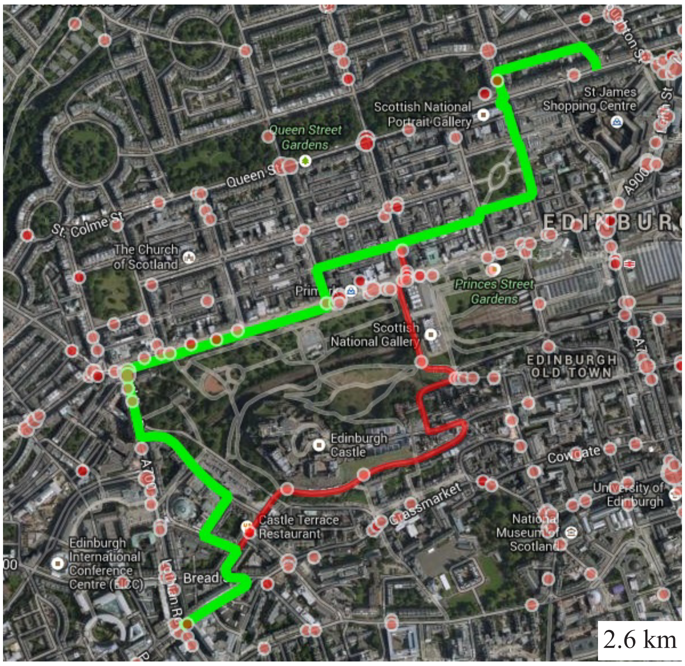
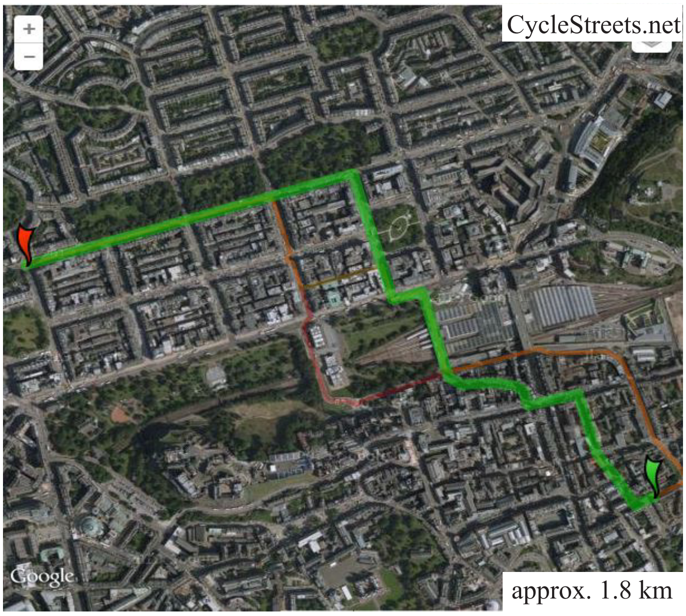


Figure 17.3:From York Place to Lothian Road

Regular cyclists group - CycleStreets preferred to accidents aware route planner

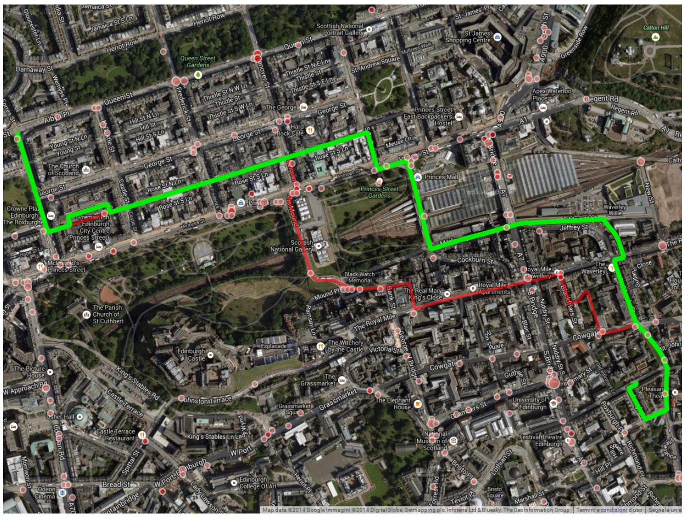
Green: quietest route, red: fastest route

Green: safest route, red: quietest route



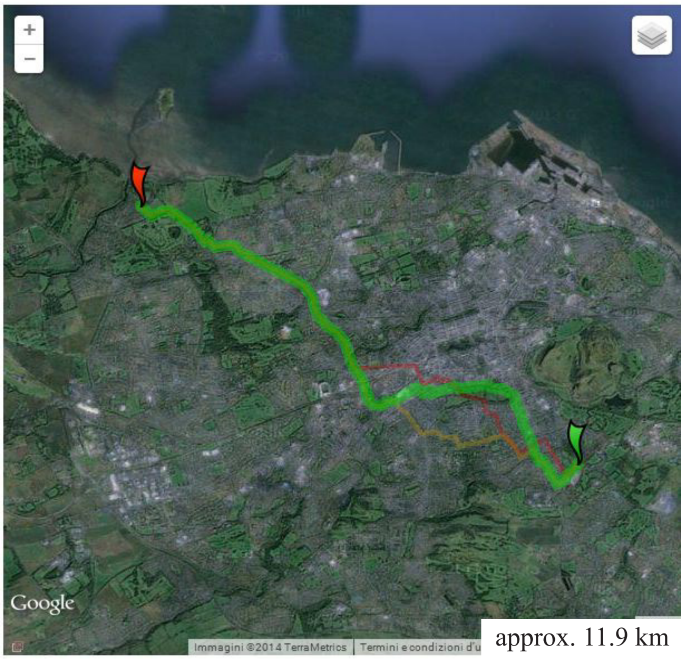
approx. 1.8 km

Accidents aware route planner

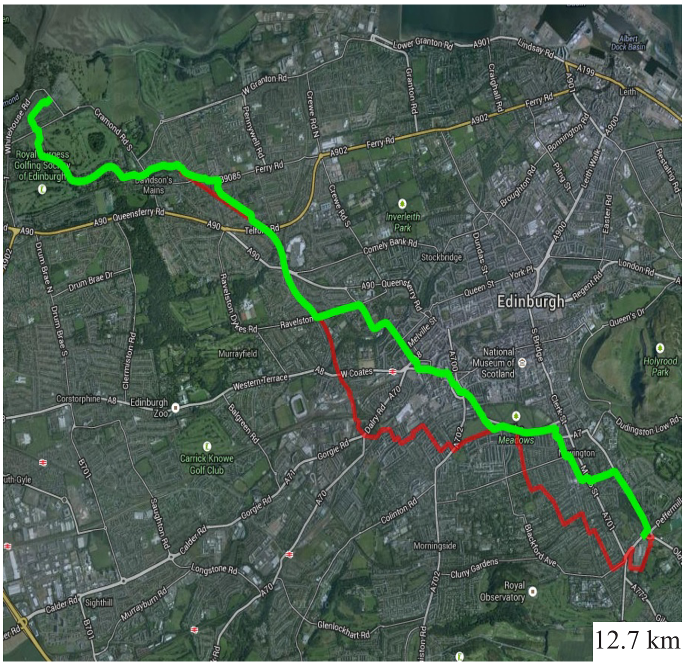


2.6 km

Figure 18.1:From Drummond Street to Charlotte Square

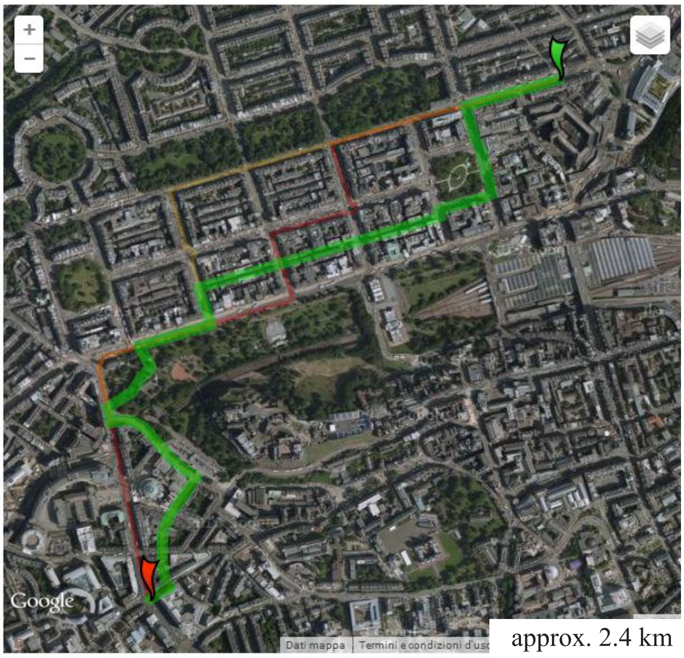


approx. 11.9 km

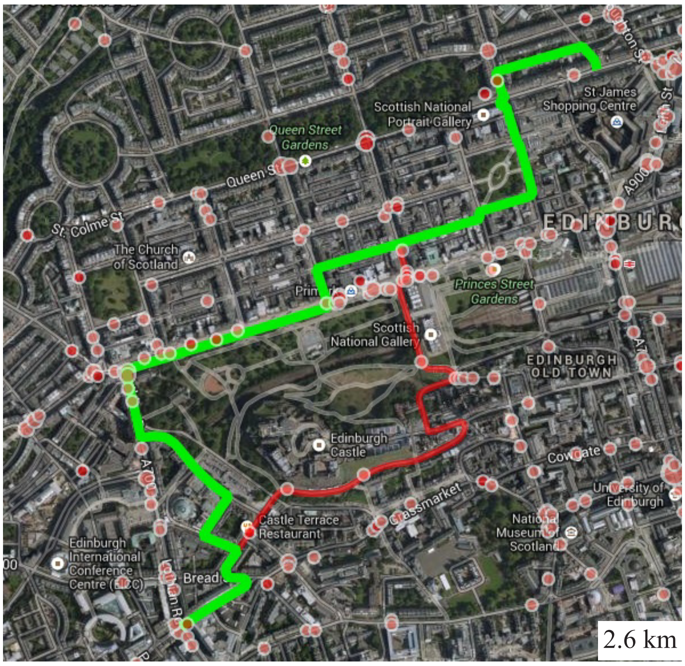


12.7 km

Figure 18.2:From Cameron Toll to Cramond Road North



approx. 2.4 km



2.6 km

Figure 18.3:From York Place to Lothian Road

Question n. 5:

"The route elaborated by the web service is effective in avoiding cycling risks". How much do you agree with this sentence?

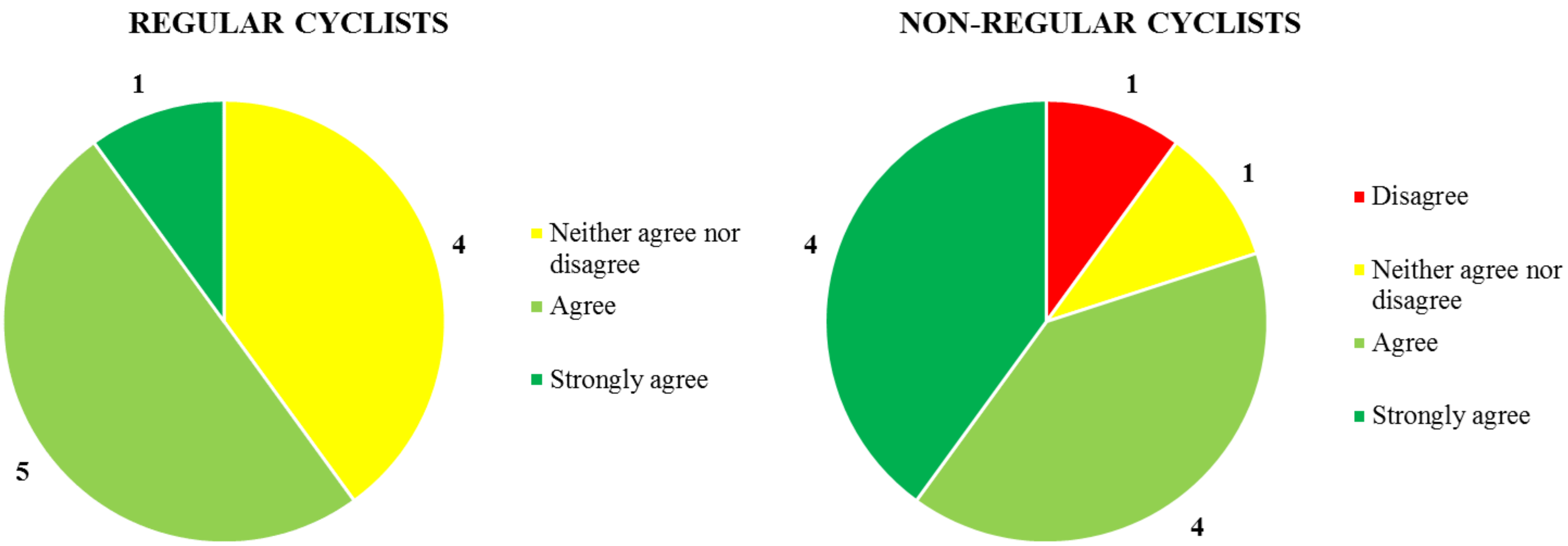


Figure 19: Pie charts showing web-GIS safe route planner surveys results for safe routing effectiveness

Question n. 6:

Once seen the routing planner results, "Next time I would consider using the route suggested by the planner". How much do you agree with this sentence?

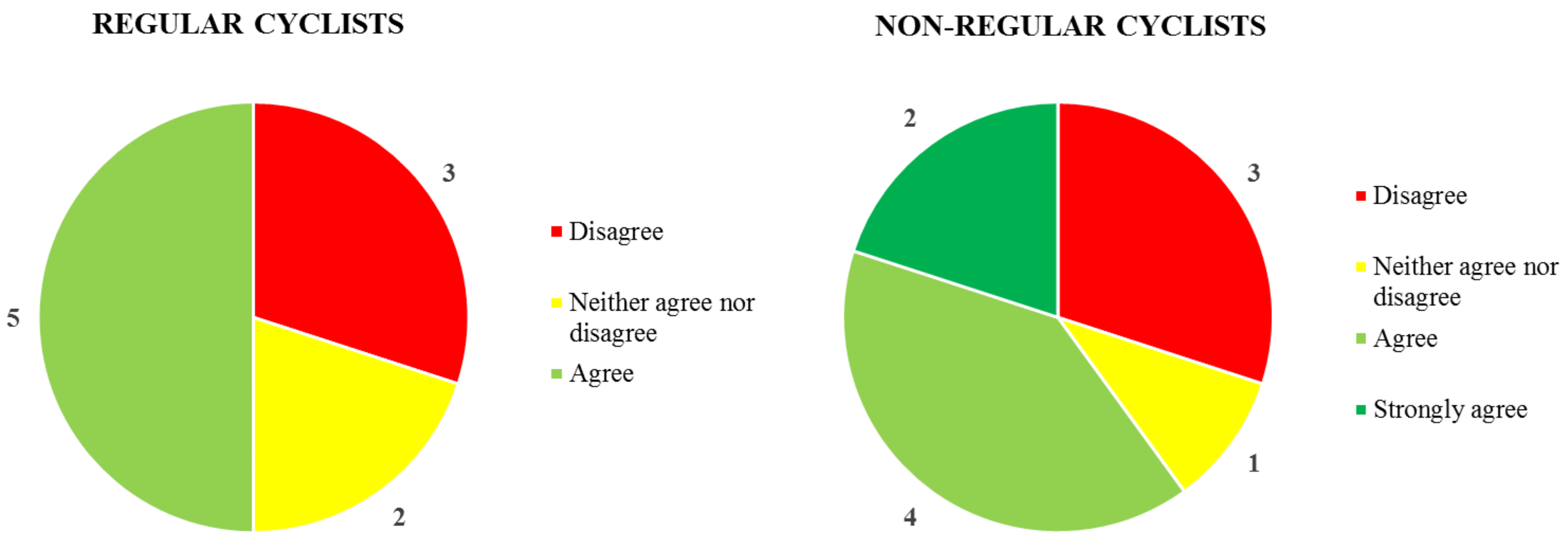


Figure 20: Pie charts showing web-GIS safe route planner surveys results for suggested safe route preference

Question n. 8:

If you had to choose one route between our web service and CycleStreets, which one would you choose?

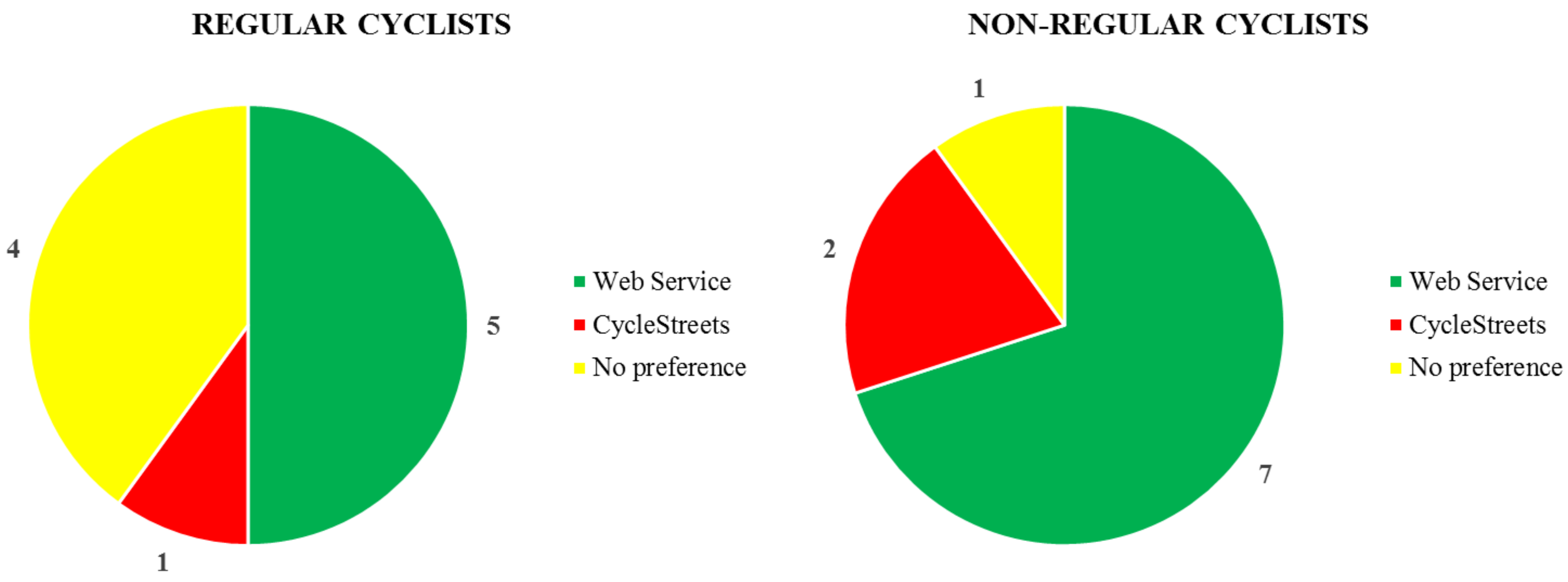


Figure 21: Pie charts showing web-GIS safe route planner surveys results for the comparison with Cyclestreets.net

5. Discussion

With this dissertation we wanted to evaluate the effectiveness of GIS, in the case of a map and a route planner, to communicate cycling risks to users; the chosen support was a web-GIS application and the dataset contained accidents location provided by DfT from 2005 to 2012. We tested our route planner with two different methods to make sure that results were consistent, to understand at which level our product can be considered usable and to raise reflections for further research on this topic regarding the users' target of such a system.

In terms of understanding visualisation techniques for risk communication, methods used by available web services are not always the most effective. In our dissertation we experimented new approaches using new features and looking beyond cycling-crash frequency, elaborating a road suitability index including other important risk factors. The exploration of new techniques filled existing gaps and revealed that the message of road risk based on complex criteria is perceived differently from experience and non-experienced cyclists.

As for the effectiveness of representation techniques, users from both groups declared to be more aware of risks and their location after seeing the map. Our representations can be considered successful; the most appreciated is the combination heat map / safest route, because able to demonstrate risk avoidance with accidents represented as hot spots, clearer to discern than punctual features.

The elaboration of a safe route choice model gave room to the comprehension of the criteria which would be worth to include in similar cases. While results highlighted by the first test tell us that our model is satisfactory in reducing risk, the same cannot be said in the second where we actually tested how this reduction is perceived. The reasons can be found in the algorithm imprecisions but especially in the criteria choice and their weighting. Our research was focused on safety and distance, but as extensively witnessed by previous studies on this regard (Aultman-Hall et al., 1997; Howard and Bruns, 2001; Winters et al., 2011; Broach et al., 2012) criteria playing a role in the choice of cycle routes are highly subjective, their consideration and weighting varies enormously dependent on cyclists characteristics.

The comparison between two groups of cyclists allowed us to assess the subjective perception of risk. Regular cyclists' perception generally reflects the model route choice in half of the cases; non-regular cyclists perceive risk to a greater extent respect to the model design and immediately after the best route choice, they still do perceive as safer longer routes. These results indicate that experience and perceived risk play a role not only in the conception of road safety, as found in Winters et al. (2012) but also in personal route choice and willingness to travel by bicycle, as found in Antonakos (1994) and Parkin (2007).

6. Conclusion

The first test made evident that safety has been effectively included, the second showed some weaknesses. Experienced cyclists do not always take into account safety and some unexperienced cyclists consider travel distance/time as more important.

We can suggest the use of our system not as a stand-alone web-GIS for safest route choice but as a valid alternative to other suggested routes; for example, the fastest and the quietest. In addition, as demonstrated by our survey this function could be highly considered by non-regular cyclists and might prompt these road users to cycle.

7. Limitations and further work

As for technical aspects, some of the most important limitations can be found in the users' answers about web-GIS service general improvements, testing and development phase have been carried out almost at the same time, it was possible to address most of the issues reported but some others remain. Distance and/or travel time are not shown, this lack would surely need resolution and a more time for development would have addressed this issue. Some users suggested the inclusion of an interactive safety weighting system, to dynamically modify routes suiting user-defined levels of risk, this would compensate the non-optimal route retrieval for all types of cyclists. The heat map could have been improved with a better separation between the hot spots and the actual accidents points. Performances in terms of time are significantly low, speed is further reduced by the routing algorithm and multiple layers on the map, this problem would be easily resolved if the web service relied on a powerful infrastructure, especially in terms of hardware.

The routing planner demonstrated to be effective in communicating risk among experienced cyclists but not enough to persuade them to choose a safer route, further research to understand whether a route planner can be the most adequate system to convey accidents risks among this type of cyclists would be beneficial.

Beheshititabar et al., (2014) tried to identify the most influential criteria in route choice for all types of cyclists, finding first distance and then safety/comfort, this study can be considered one of the few that attempts a comprehensive approach, more research might confirm or confute this methodology. If it is possible elaborate a model able to include most choices for the majority of actual and potential cyclists their perspective will surely contribute to the outcome of similar projects on cycling risks communication.

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PART II

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Technical Report

1. Introduction

The technical report has to be intended as a constituent part of the entire dissertation submission. It must contain a more description of the overall work that brought to result with a special attention to those details that have been omitted from the main research paper mainly for a matter of space rather than for a matter of non-conformity or non-consistency with the previous part. This is particularly true in this case, the product of our work that had developed in the course of the second semester of the academic year, and with more intensity in the last five months, has been characterised by the experimentation of different approaches to the research work. The test of different analysis techniques, supporting software, dataset, outputs and methodologies has allowed the development of a vast amount of collateral research material which nevertheless it will possible to cover in this document. What we want to make clear is that all the work that has accompanied the development of the supporting document has surely been beneficial both for the didactical aim of the piece of work which the dissertation consists of and for the interesting sparks of further research that is possible to extrapolate from this document. In conclusion, the work here presented is the demonstration that the development of the dissertation has been anything that a linear and unvarying process that shows how that document is not in fact something that could be considered finished and completed but still full of suspended points and questions that only further research could help to enclose and respond.

In the first part of this technical report we will explain what led us to choose for the web-GIS service option to represent our result describing the results of the survey that helped us to identify potential user requirements. We will then describe how accidents data have been processed and structured in our database. In the third part we will describe different methodological approaches to the identification of road risks, describing their characteristics and the reasons for which these have not been preferred to the actual methodology. We will describe how we weighted the two criteria of length and risk in order to decide the costs of network edges and we will finally present the complete results of the users' test of our web-GIS service.

2. User requirements survey results

The initial idea of the final product of this dissertation was a mobile application, design principles and development process would have been different respect to the actual final outcome. The mobile application would have seen the mobile device warning for cyclists of potential risks while cycling on roads. The conceived system would surely have opened many questions regarding how to communicate danger to cyclists without being distractive, thus adding risk to the road itself. This was an aspect that initially was underestimated and thanks to the results we are about to show has made us decide to change the scope of the dissertation product for something more respondent to user requirements. In addition, the development of a mobile application would have required the study of a programming language, Java adapted to Android development that we considered after some initial trials as inopportune, because temporally too extended, for the scope and the time scale of the dissertation work. We are not going to present here all questions that were submitted to users but just those we judge as relevant to our final result. The methodology used was an on-line survey in which we presented to potential users different options, some based on mobile platforms and others on web. We managed to interview 38 people asking additional questions about their cycle habits and safety approach to cycling, this is to have an idea of how much the theme of cycling safety is considered amongst the public, the number of interviewed people is surely far from being considered a significant sample but, given the aim of this initial survey we decided to assume results as statistically relevant. As some of the questions are not related to the development of the web service I will include here just questions that later became useful for our research. Questions were inspired from other similar surveys that have been conducted in the event of past GIS dissertations which had as main focus the production of GIS front-end consultation services (Terzis, 2010; Loughlin, 2013; Richardson, 2013; Jui-Wen, 2013).

Question 1:

What is your age?

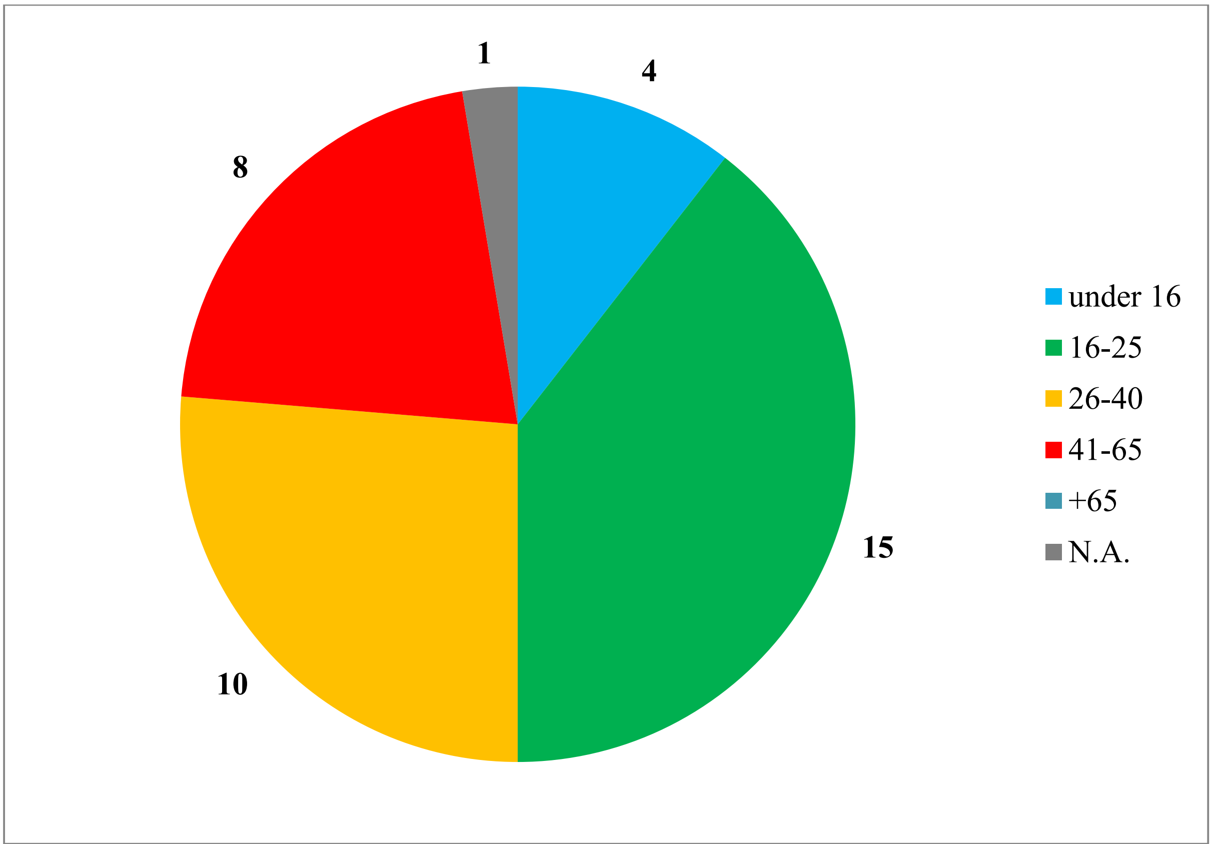


Figure 1: Pie chart representing the distribution of age among initial survey respondents

The majority of respondents to our online survey have between 16 and 40 years old, this is coherent with the most current UK statistics regarding internet usage (ONS, 2014) that quantify in 99% and 96% the percentage of people respectively between 16 and 34 and between 35 and 54 who have used the internet in the first four month of the current year. We can then assume that people who participated to the survey are actually people who frequently use internet and might be interested in a web based GIS service.

Question n. 2:

In a week of your everyday routine, how frequently do you cycle?

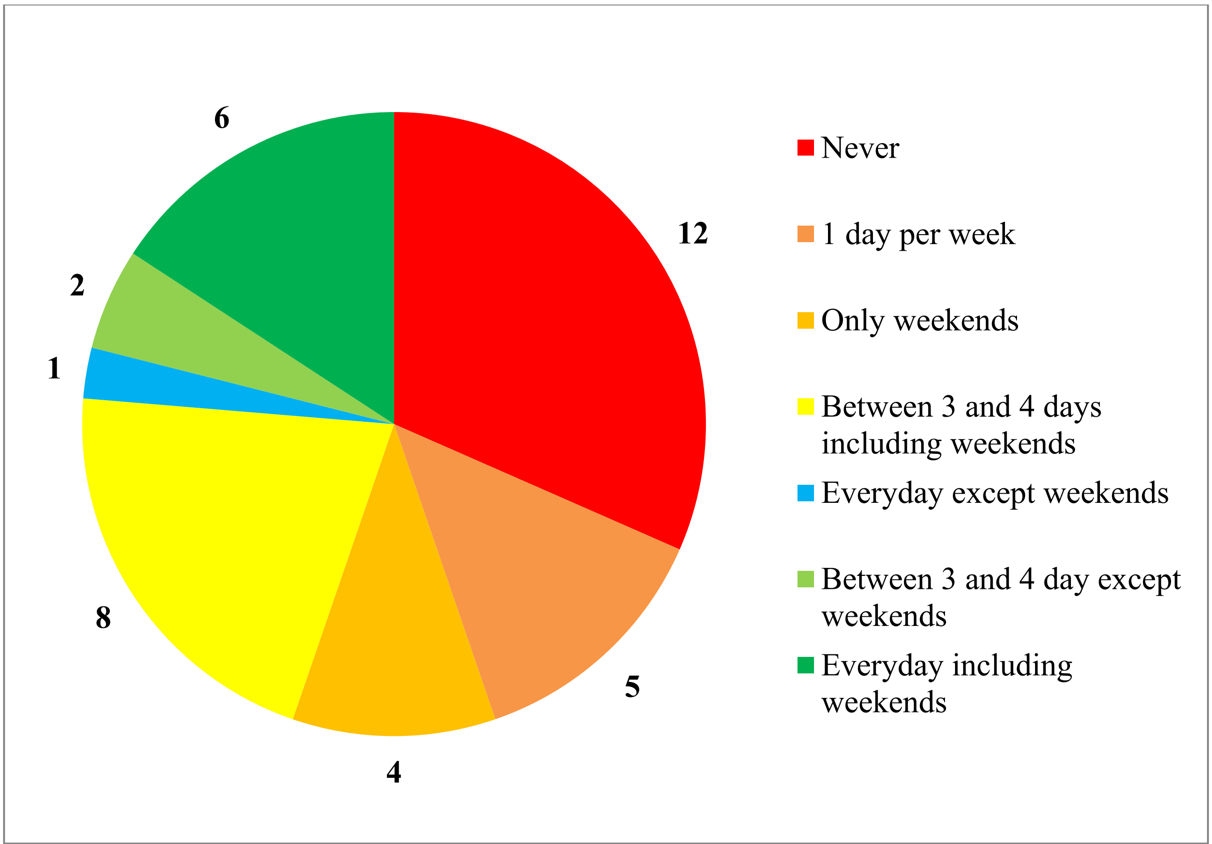


Figure 2: Pie chart representing intensity of cycling among initial survey respondents

56% of respondents declared to cycle less than three days in a week, including weekends. If we include those who cycle 4 days per week we have 77% of respondents; on the other hand we have 16% of frequent bike users, cycling every day, which becomes 22% if we consider those who cycle at least 4 days except weekends. From this statistic we can infer the general low propensity of British people to cycle, this was found as a discriminant factor in the judgment of the final results in the second survey, indicating that people that actually do not cycle frequently might be more sensitive to the perception of risk and consequently prone to consider a safety route planner (Cristofori, 2014).

3. Accidents database design and selected information

This brief chapter wants to describe the structure of the accidents database, containing all information needed to perform the analyses and to visualise data on the web-GIS. Its design has maintained the STATS 19 format although information was manipulated, excluding what was not directly related to our study and adding analysis results on suitability (see Cristofori, 2014).

The primary key "id_accident" identifies uniquely each accident which can have multiple vehicles and casualties involved; each vehicle can have many casualties but only one accident and in turn one casualty can be involved in just one accident and be related to just one vehicle. In order to achieve the identification of each single vehicle and casualty per accident, maintaining a link with the accidents table, vehicles and casualties can be linked with a compound key consisting of the unique identifier for each accident and a vehicle reference; this is a foreign key to the casualties table which in turn adds a reference to identify each single casualty on the same vehicle.

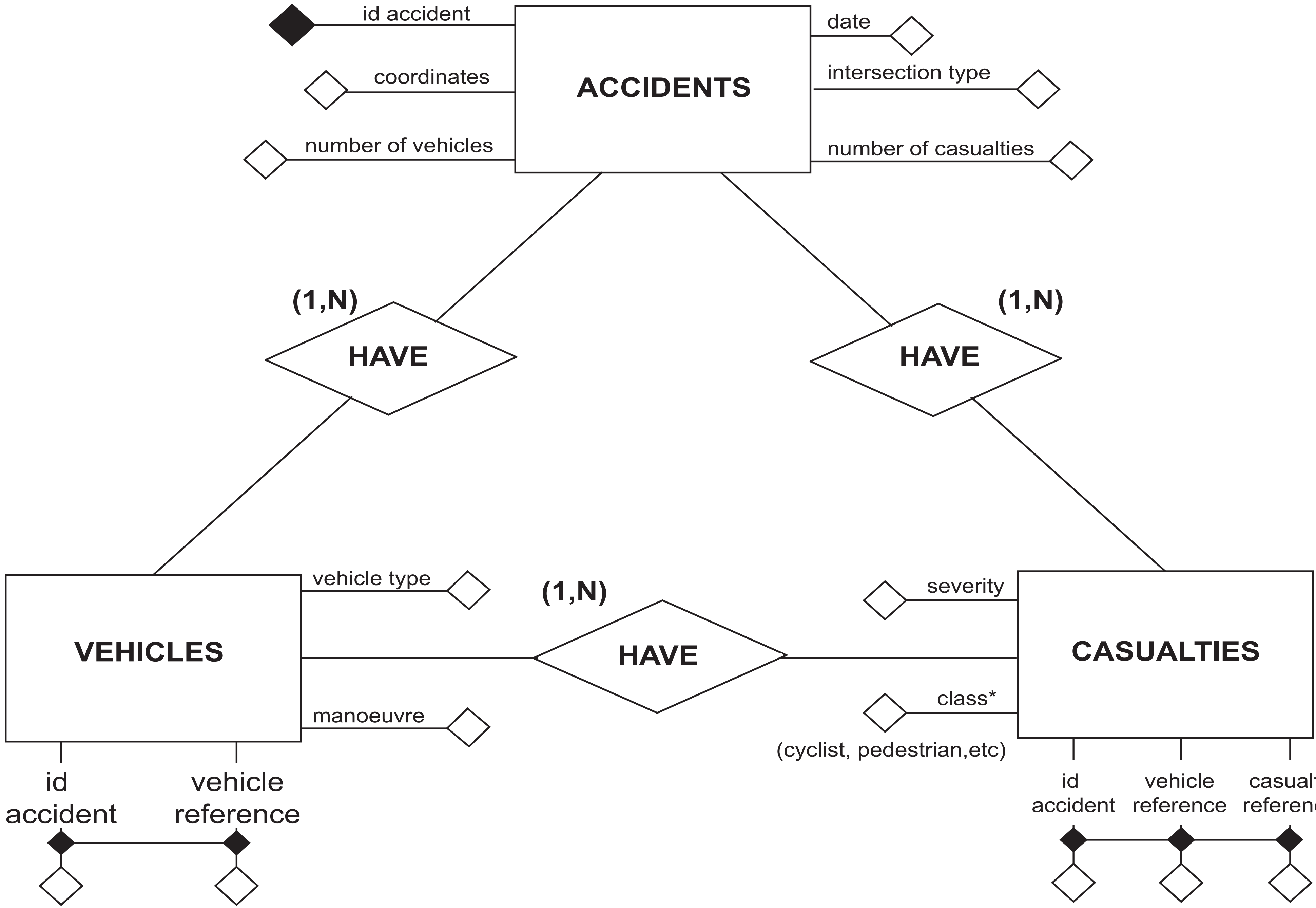


Figure 3: Outline of accidents database structure

4. Accidents Hotspots Identification Methodologies Comparison

When we talk about risk, we refer to the risk for the cyclist to incur an accidents (Vandelbulcke et al., 2014). There are a lot of methodological approaches to identify and quantify it, those can differ from the analysis technique which usually is subordinated to the general aim of the research (Schepers et al., 2014; Yannakoulias et al., 2012). As our research focus was on the communication of risk at a street level one of our main concerns was the research of the right technique to detect risky areas including selected information without being too dispersive. In first attempts the identification of accidents hot spots was thought as the most appropriate, the method was also tested with a Crash Risk (CR) approach. The exploration of different methodologies showed the Crash Frequency (CF) approach more incisive in reporting results relatively to the scope of the dissertation and available data.

4.1 Literature review on accidents hot spots identification

There are various examples on literature using different accidents hazards identification techniques. In Anderson (2009) on our same dataset in Central London, Kernel Density Estimation (KDE) is used to identify spatial patterns of accidents and K-Means to characterise found hotspots with other environmental factors such as the presence of pedestrian crossings, schools, underground stations, etc. This approach has not many precursors in related literature and presents an effective methodology to integrate additional information to the sole spatial data. Moreover, in many passages of this paper is described the advantage of using KDE because of the effectiveness in determining the surrounding area for each accident thus of areas of future accidents likelihood. There is another study that deals with the comparison between different conventional and spatial hot spots identification techniques for road accidents (Yu et al., 2014). Different techniques underwent multiple tests and their performances were compared to three quantitative evaluation criteria; KDE was the method that scored best after, Empirical Bayesian methods. In general researchers found that spatial analysis-based methodologies performed better than Crash Frequency (CF), the one used in our project (Cristofori, 2014) and Crash Risk (CR) approaches. The main drawbacks that KDE presents are the solely evaluation of the spatial dimension of the accident event the application of a 2D Euclidean spatial model over phenomena, namely cycling accidents, that are often distributed within a network. Attempts to address the first types of issues can be found in Anderson (2009) and regarding the second types a NetKDE approach would be preferable as in Xie et al. (2013), where the technique was combined with Local Moran's I Index to find statistically more significant hot spots, in terms of spatial density. From what we can infer from past experience in hot spots identification KDE is the most used techniques, this is used sometimes alone in order to detect accidents spatial density hotspots while it is combined with other methodologies when deeper results in terms of related accidents environmental factors have to be achieved. As for other hot spots identification techniques, regarding road accidents, nearest neighbour is used in Nicholson (1999) and Keskin (2011), in the latter especially this technique is preferred to the so-called "quadrat approach" which involves the superimposition of a grid to the study area and the count of accidents within each cell, this technique shares its principle with Spatial and Temporal Analysis of Crime (STAC) see Block (1998).

4.2 Kernel Density Estimation

KDE cannot be strictly defined as a hot spot identification technique, it is instead an interpolation routine but it is widely used to detect hot spots. As we do not think this is the appropriate place to describe extensively its underlying principles, as these have been elsewhere discussed (Simth and Bruce, p.61, 2008), we will just highlight the characteristics that were evaluated in our work and affected outcomes.

We can imagine a kernel as a symmetrical surfaced place upon each point with this falling in the geometrical centre of the surface, in this case each point is an accident. We can then imagine each point having a value and this value is spread concentrically across the area covered by the surface with an intensity which is dependent on the shape of the surface; values will decrease dramatically if the shape has a triangular form, linearly if it has a triangular form and increasingly more smoothly the more the surface over the points tends to be flattened. Once all values are established for each location under the surfaces the study area is overlaid with a grid and each cell grid receives the correspondent value of its centroid. If two kernels overlays their values are summed and this happens in case of multiple points on the same location.

The kernel shape defines results smoothness, with triangular and negative exponential distribution functions values tend to fall more sharply and found hot spots will appear more circumscribed; conversely quartile, uniform and normal distribution functions will result in more spread appearance hotspots, covering larger areas. One of the principles for our study was the usage optimisation of our data, this means the maximum information we could get in the maximum spatial detail, this is to the respect the spatial distribution of accidents occurrences, which usually take punctual shape when at intersections (non-stationary and isotropic) and linear when along critical road segments (non-stationary and anisotropic); we can infer from this that our hotspots needed to be as most focused as possible, consequently after some attempts with normal distribution function we found the triangular function the most suitable for achieving the wanted results.

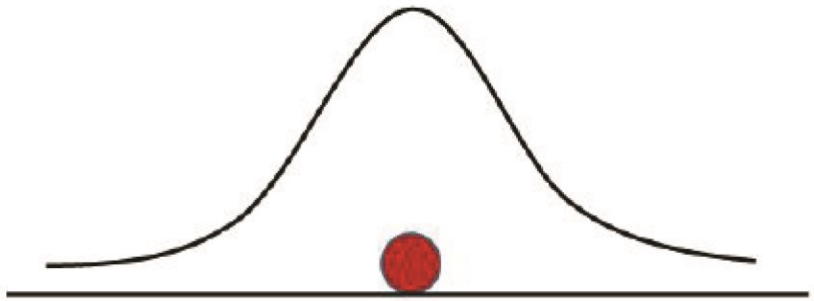


Figure 4: graphical representation of the normal distribution function

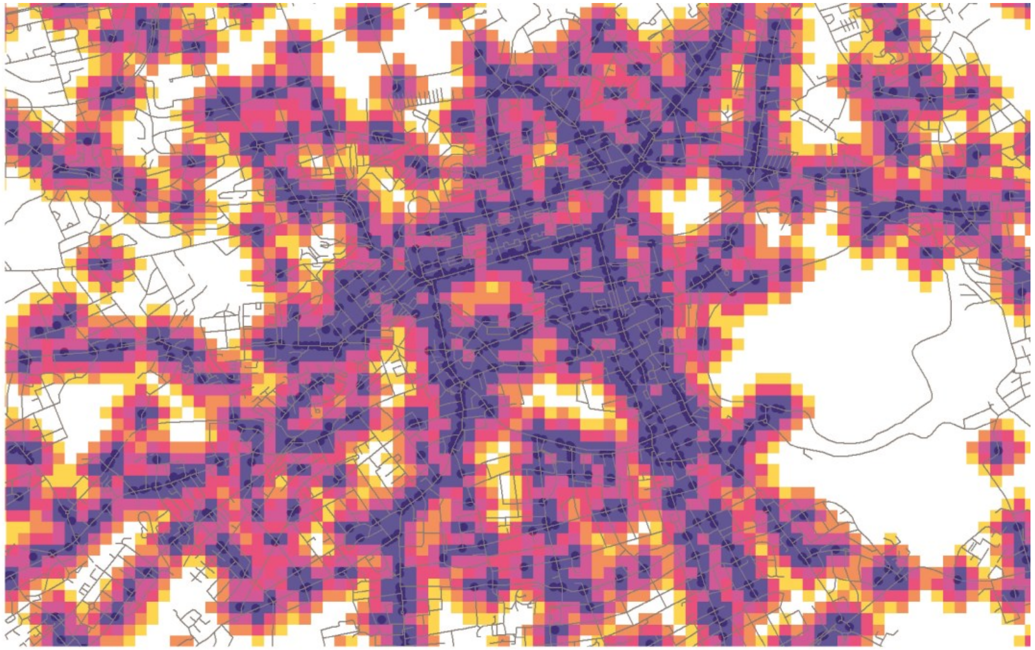


Figure 5: cycling accidents 2005 - 2012 in Edinburrgh City centre represented with KDE, normal distribution function

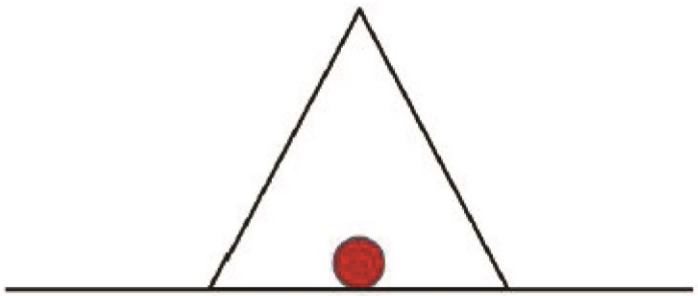


Figure 6: graphical representation of the triangular distribution function

Figure 7: cycling accidents 2005 - 2012 in Edinburrgh City centre represented with KDE, triangular distribution function

4.3 Distance approaches

These methods are based on the calculation of distances between points which our dataset consists of, as each technique has been extensively described elsewhere, i.e. Smith and Bruce (2008, p.52), we do not think it is necessary to describe how each of them works, rather motivating their use in our research. Although we did not find a relevant number of examples of the utilisation of these techniques for road accidents, we decided to experiment them because one interesting aspect of distance-based approaches is that they are often preceded by a preliminary study on the whole dataset to quantify and assess its general level of clusterisation, this preliminary test is called Nearest Neighbour Analysis (NNA).

4.3.1 Nearest Neighbour Analysis

The methods calculates the distance of each point in the dataset, computes its mean and then compares this value to the value expected if points in the dataset would follow a random distribution. The algorithm returns a value, the Nearest Neighbour Index (NNI), which ranges from 0 to potentially infinite. If this value tends to 0, this means that our dataset is more clustered than expected if our points were randomly distributed. If our value tends to 1, this indicates that points in our dataset have the same distance than that expected in a random distribution, and if this value is greater than 1 this means that the points in our dataset might present a dispersed distribution. The analysis on our accidents dataset was conducted using the software CrimeStat 3.3. In our dataset the NNI is 0.03036, this indicates an evident clustered structure of accidents, as a consequence we will expect subsequent analyses to return hot spots.

```
Nearest neighbor analysis:
--------------------------

    Sample size........: 1902
    Measurement type...: Manhattan
    Start time.........: 05:50:47 PM, 07/24/2014

    Mean Linear Nearest Neighbor Distance ...:  139.10 m
    Minimum Distance ........................:  0.00 m
    Maximum Distance ........................:  49550.00 m

    Based on User Input length:
    Length ..................................:  1753640.00 m
    Mean Random Linear Distance .............:  458.11 m
    Nearest Neighbor Index ..................:  0.3036
    Standard Deviation ......................:  303.29 m
    Standard Error ..........................:  6.93 m
    Test Statistic (t) ......................:  -46.0286
    Degrees of Freedom ......................:  1901
    p-value (two tail) ......................:  0.000001

    End time...........: 05:50:47 PM, 07/24/2014
```

Figure 8:NNA analysis results

4.3.2 Nearest Neighbour Hierachical Clustering

The underlying principle for this technique is the same explained in the above paragraph, but this time hot spots are located on the map. The routine iterates the comparison process initially for each point, identifying as hot spots those clusters in which points' distance is shorter than the expected, first order hotspots. The same process is then iterated between found clusters using their centroid using as reference, creating further hotspots orders, until no more clusters can be found (Smith and Bruce, 2008, p. 53). In our research results are presented as ellipses enclosing hot spots, these constitutes an smoothened representation of the hotspot used both to facilitate interpretation and to allow a more realistic "fuzziness" of hot spots location, especially in this case when we are about to deal with diachronic data. Underneath the ellipse area we won't find all points belonging to the hot spot but just those that fit the ellipse which area can be set on the basis of the standard deviation of values in our data. In our representation we decided to use 1.5 standard deviation ellipses, as optimal solution suggested by Smith and Bruce (2008, p. 54) setting to 8 the minimal number of points of each hot spot (fig. 9).

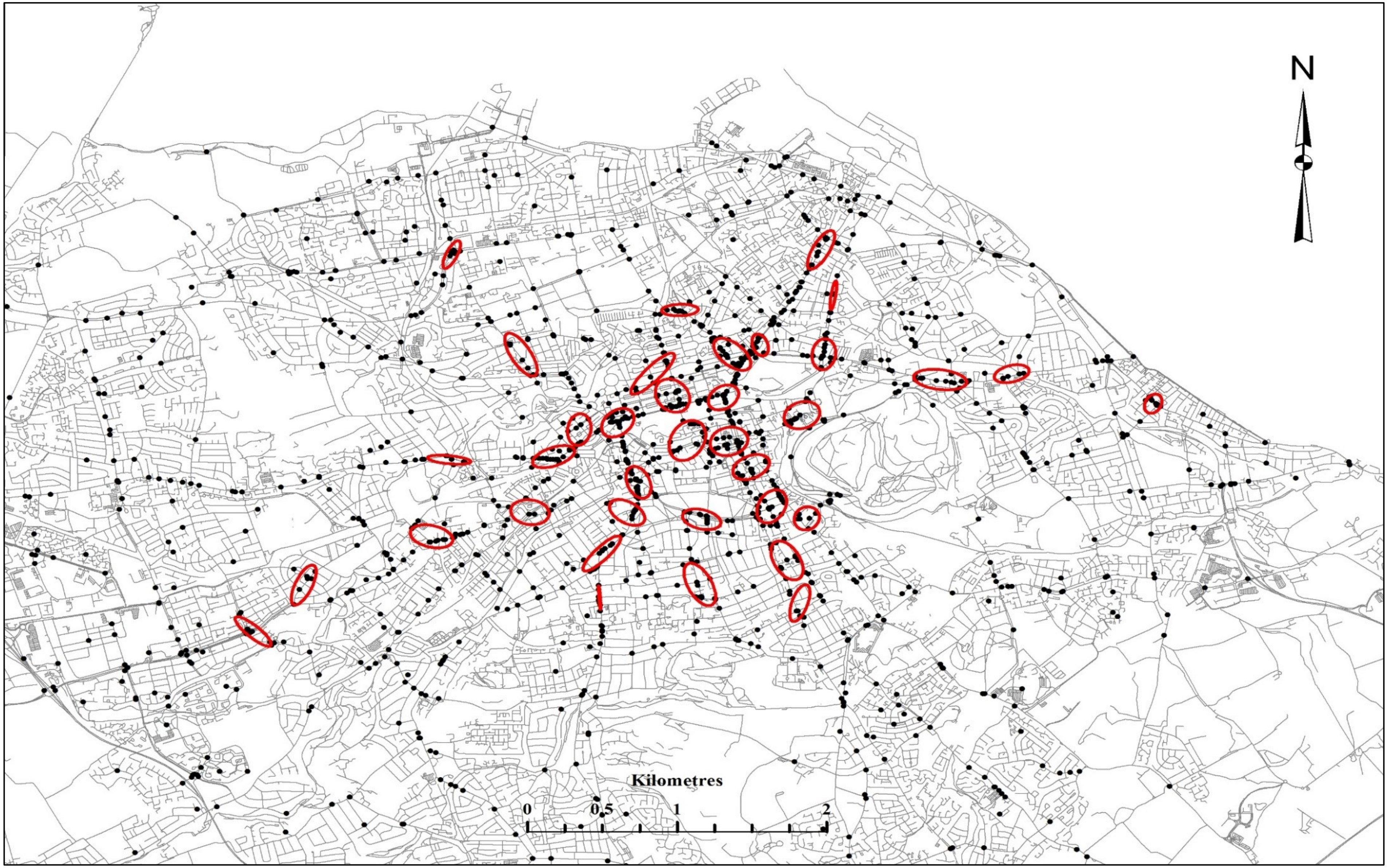


Figure 9: cycling accidents hot spots in Edinburgh City found with Nearest Neighbour Hierarchical Clustering Analysis

4.3.3 Risk Adjusted Nearest Neighbour Hierarchical Clustering

Our exploration of distance-based techniques went further, considering also a risk adjusted approach, we found in literature many examples confirming that such a methodology is to prefer to a mere crash frequency one (Yu et al., 2014) as it takes into account traffic exposure, differently from the former that assumes a uniform distribution of traffic across the study area, which is not correspondent to reality. As measure of exposure to risk we used Annual Average Daily Traffic/Flow (AADT or AADF) as suggested by Schepers et al., (2014), these data for our study area were sourced from UK DfT traffic counts website (http://www.dft.gov.uk/traffic-counts/). We considered the daily average number of bicycles in transit to the 81 counters placed along major road junctions during the same time period of accidents investigation (2005-2012). It is evident that just these few measurements cannot convey traffic density in the entire study area, as a consequence values needed to be predicted with interpolation.

GIS analysis offers the possibility to choose among several interpolation techniques, some examples we can cite are Geographic Weighted Regression (GWR), simple Kriging or Universal Kriging. In GWR predicted values are assigned according to the degree of relationship (regression) between space, in this case local, and the phenomenon under investigation. In Kriging values are assigned on the basis of the spatial correlation of all points in the data set, the relationship between known points' values and their distance is mathematically measured and depicted in a function called empirical semivariogram, after that, values to unknown points are assigned fitting the empirical semivariogram to other modelled semivariograms (circular, spherical, exponential, etc.) on the basis of both distance of single points and total spatial autocorrelation (ESRI, 2012). Simple and universal Kriging differs in the use of a different model fitting method that assumes, in the latter, the presence of a certain trend in our data.

The main issue regarding the interpolation of AADT counts is the prediction of non-Euclidean characterised spatial data. In a research on interpolation accuracy Smith et al. (2003) declare that the most accurate methods of interpolation in network environment are statistical, as capable of maintaining data natural characteristics. The authors doubt that Euclidean based interpolation methods can actually work well in complex networks where traffic, barriers and regulations discontinue their linear foundations, according to which nearer objects are more similar than further ones. However, authors affirm that most studies about link-based traffic data interpolation adopt traditional Kriging. Another study which is worth to mention is (Selby and Kocleman, 2013). Authors compare Geographical Weighted Regression to Universal Kriging using them both with Euclidean and network techniques; they assess the major accuracy of Kriging at predicting AADT data, moreover they conclude that Euclidean distance based Kriging performed just about as well as network-based metrics, adding that the complexity of the latter complexity does not compensate accuracy results.

All mentioned aspects were considered when evaluating the right interpolation method. Unfortunately statistical data on cycling fluxes, that could allow the elaboration of origin/destination matrices for all roads do not exist, thus we had to choose a spatial-based approach. To this must be added the low quantity and non-uniform distribution of counters, principally located on city main access roads (in which cycling is not recommendable) and in the city centre. In addition, the GIS desktop software we had for our analysis (ArcMap 10.1) does not allow network based interpolation.

Interpolated values were averaged AADT data for each counter in the eight years period analysis (fig.10); after a number of attempts with diverse techniques we opted for Universal Kriging with exponential semivariogram model, which produced an interpolation surface appearing more correspondent to a hypothetical cycling traffic distribution (fig. 11).

Once we produced the raster surface we had to transform our data in a format that CrimeStat would have interpreted as “secondary file”, “at risk” population represented by annual daily average number of cyclists, against which we would finally perform the hot spots analysis. To do so, we transformed our raster grid into a points grid, assigning to each point the value of the correspondent underlying cell. We finally ran the analysis on CrimeStat using the same parameters used in NNHC for ellipse extension and minimum number of points per hot spot (fig.12). Although CrimeStat 3.3 allows network based interpolation, which would have surely brought more significance to our results, all attempts had to reckon on the high computing memory usage that this method requires. Such a working level was not supported by our hardware and all attempted analyses were interrupted by the “Out of Memory” message, resulting in the application crash and loss of all settings.

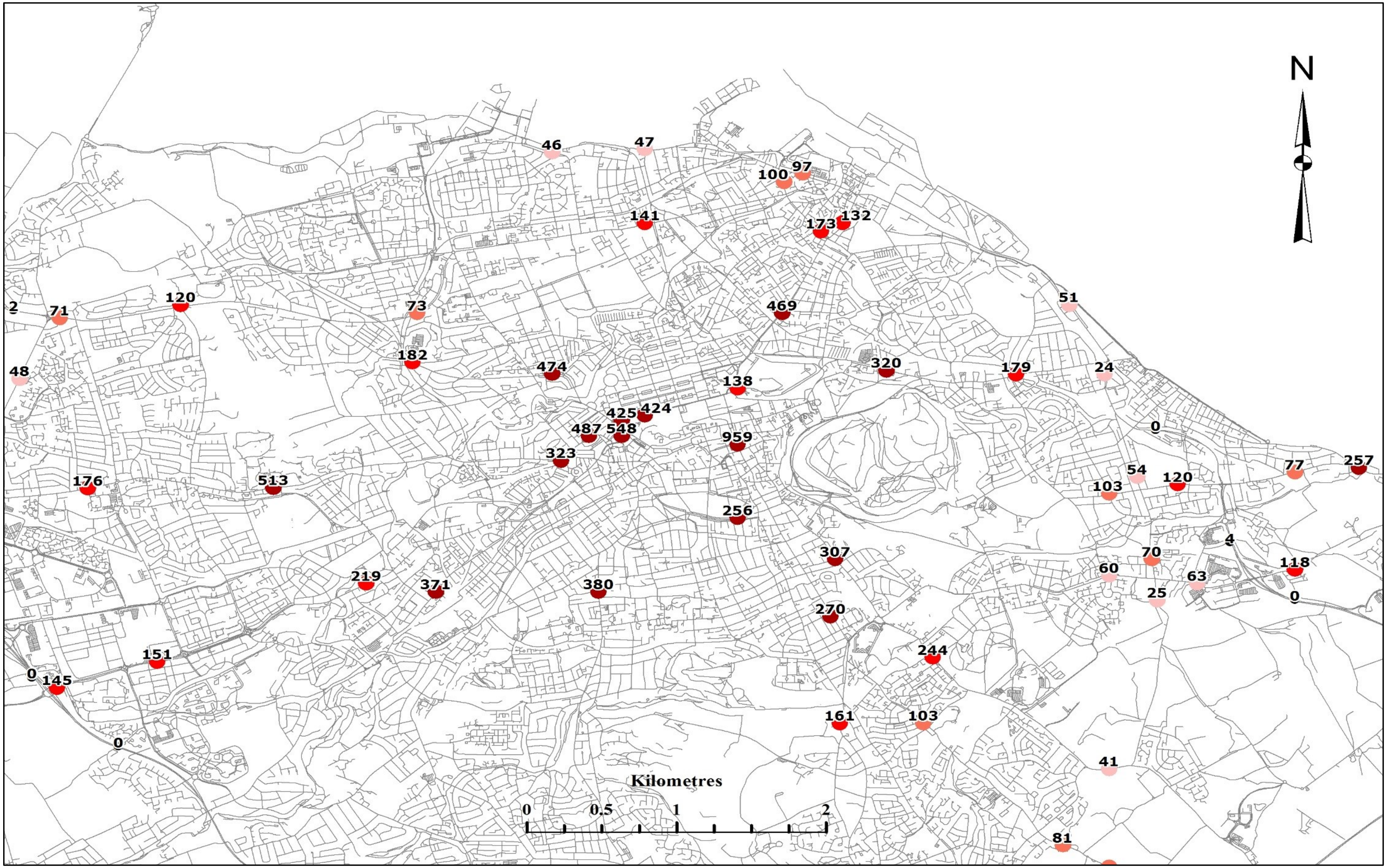


Figure 10: distribution of traffic counters in Edinburgh City centre area showing the average bicycles AADT between 2005 and 2012, source UK DfT

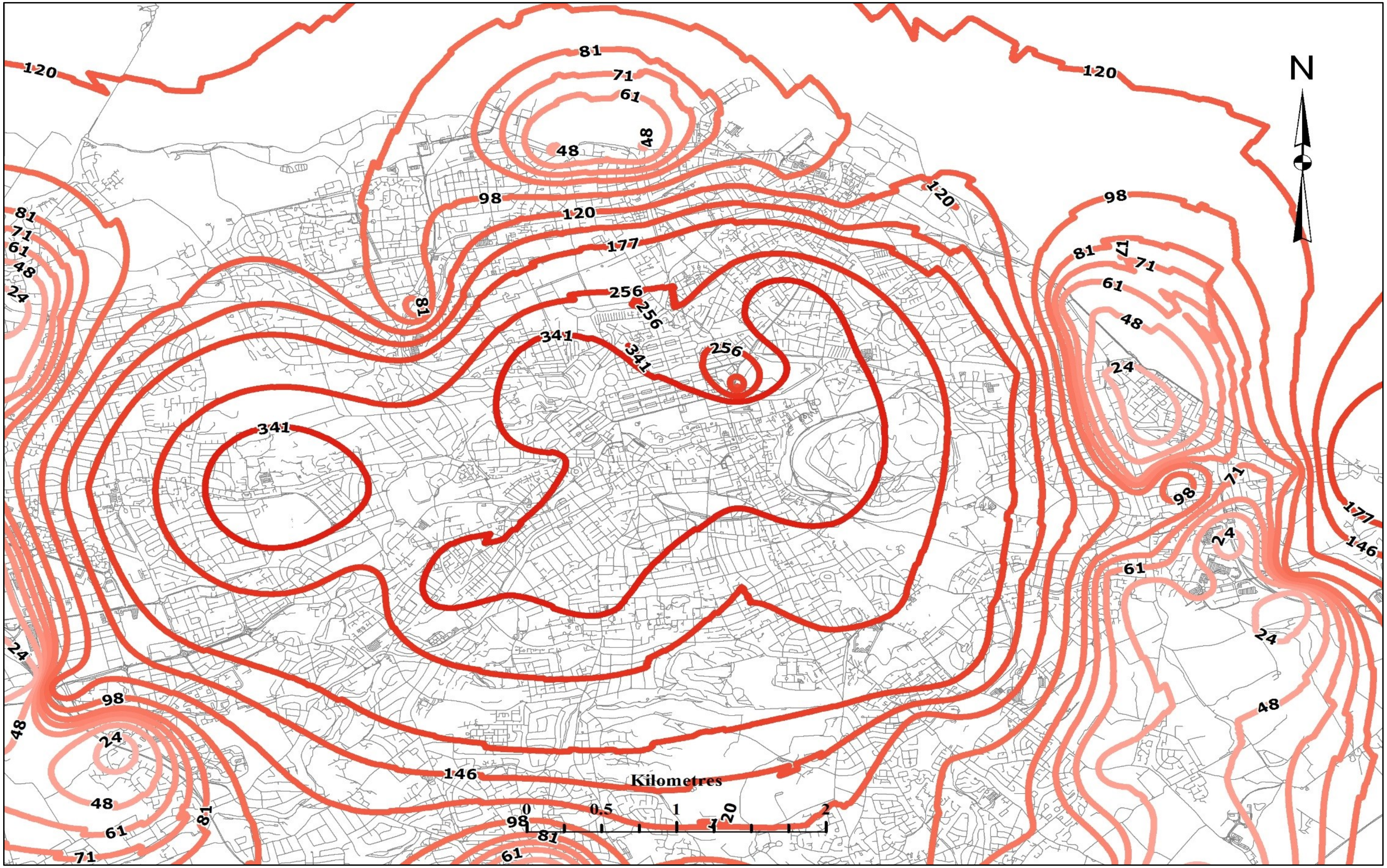


Figure 11: universal Kriging interpolation results of average bicycles AADT between 2005 and 2012, source UK DfT

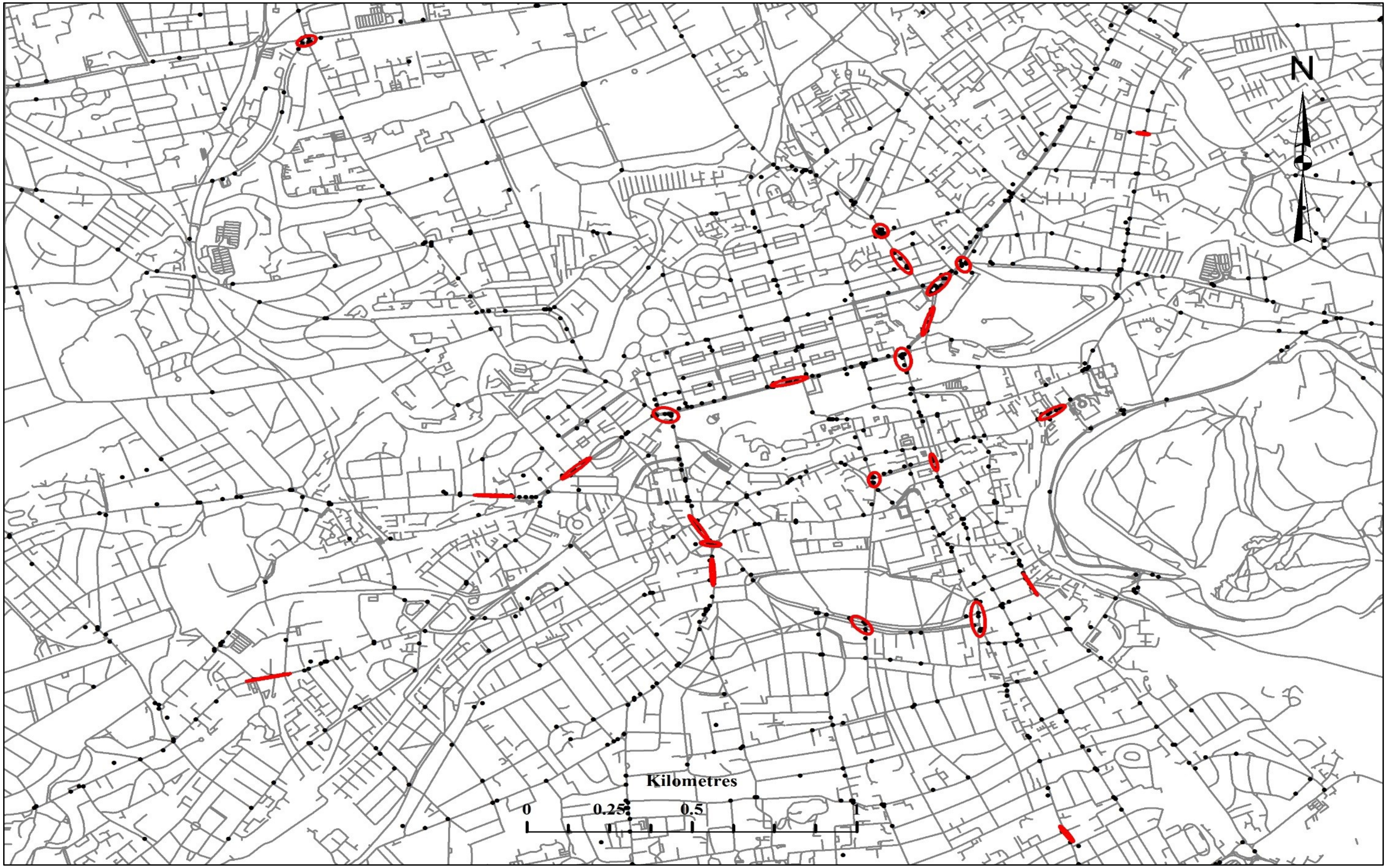


Figure 12: cycling accidents hot spots in Edinburgh City found with Risk Adjusted Nearest Neighbour Hierarchical Clustering Analysis

4.4 K-means Clustering

The main characteristic of this technique is that the number of hot spots is set by the user prior to the execution of the routine. The algorithm initially conceives our data, in this case all our points, as a unique entity and starts calculating hot spots centroids finding the minimum distance distances from all objects in that hot spot, the number of hot spots is the same defined by the user. The algorithm iterates the process until the distance of all points to their assigned cluster cannot be further minimised. In considered literature we have never found the use of sole K-means to detect cycling accidents hot spots, but a very interesting approach including this technique is brought by Anderson (2009) in which this method is used to characterise KDE found hot spots. The evaluation of this method in our study was characterised by many attempts that regarded especially the choice of the right number of found hot spots, remembering that we wanted them to be the most punctual as possible we always opted for high number with high values of separation between them, so as to keep them the smallest and most focused as possible. We finally chose an arbitrary number of 100 hot spots and 1.0 as separation, shown ellipses enclose 1 standard deviation (fig.13).

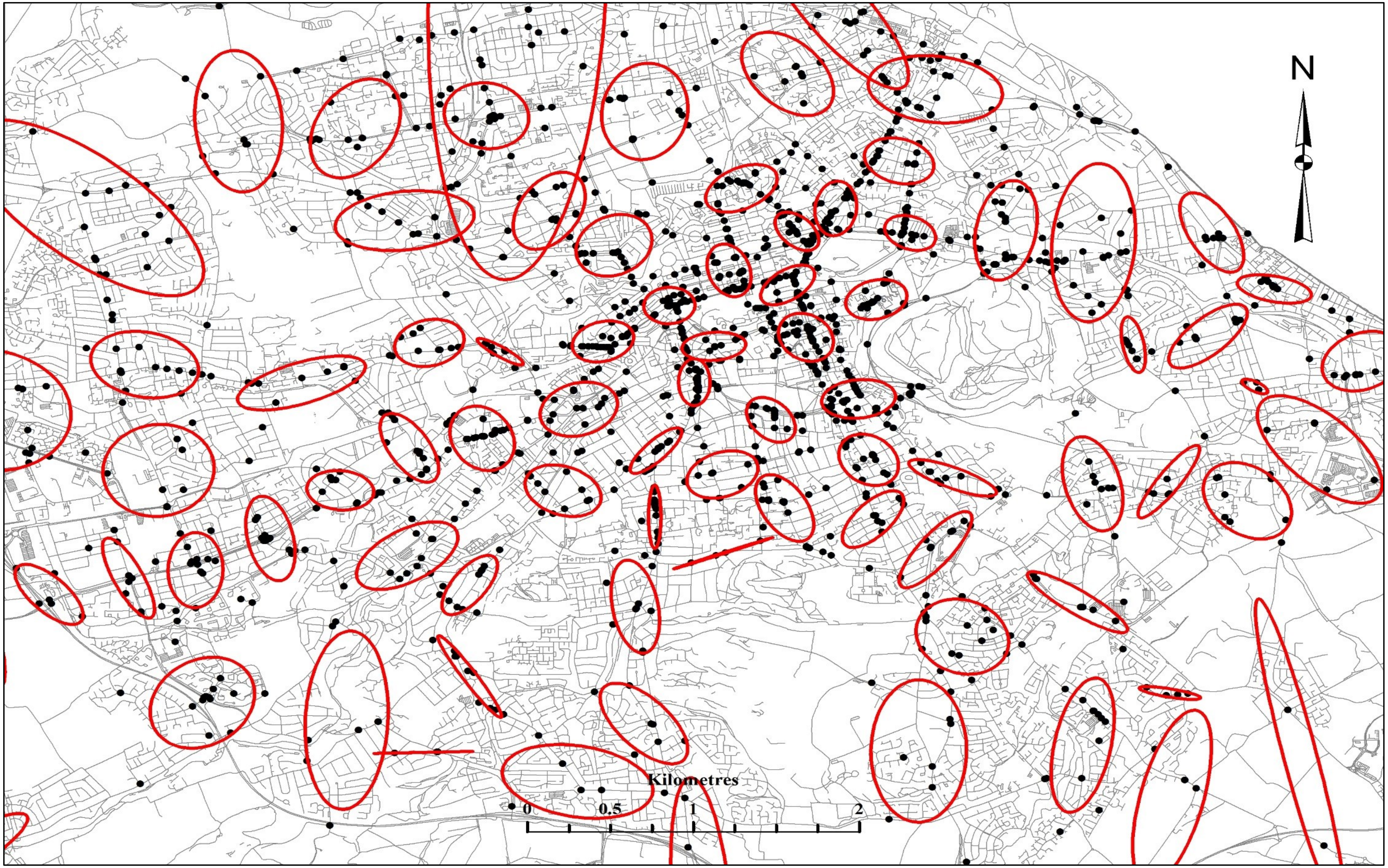


Figure 13: cycling accidents hot spots in Edinburgh City found with Risk Adjusted Nearest Neighbour Hierarchical Clustering Analysis

4.5 Results discussion

Results of each technique were visually evaluated to assess which methodology looked the optimal for our objectives; clear recognition of spatial distribution patterns, hot spots number, size and shape were the criteria used in the evaluation.

KDE with triangular distribution function demonstrated to be the most effective methodology for detecting cycling accidents hot spots in our study, hence confirming literature findings. Hot spots are well identified, dimensions are small and events boundaries are crisp and circumscribed to actual events, moreover the grid representation succeeds at conveying effectively the density, it is possible to clearly distinguish multiple accidents on the same location from single accidents thanks to colour gradient. The main limit of KDE is the fact that it returns information on spatial density, without adding additional information to the mere spatial one. Our objective was not only hot spots identification but also their characterisation for further work, casualties' severity, vehicles involved, type of intersection, etc. The result would have been achieved resorting to other hot spots techniques in combination with KDE but this was not the scope of our dissertation. The exploration of this technique revealed its validity for accidents (not only those regarding bicycles) and we do think that the approach adopted by Anderson (2009) would surely bring very interesting results if used in Edinburgh, both in terms of knowing accidents patterns and in support to the elaboration of road safety policies.

Distance based approaches can also be considered a valid technique, NNA highlights a pretty strong accidents clusterisation tendency, this is positive because we recognise that cluster patterns are product of an underlying spatial phenomenon but at the same time is a limit because of the low number of significant hot spots, this is even more evident RA NNHC. Hot spots shapes and sizes with these techniques are suitable for further analysis, it is possible to recognise accidents along streets from those at intersections; we especially appreciate the definition of hot spots in RA NNHC, yet their number remains too small. Another limit regarding this method is the unequal distribution of traffic counters that produced an interpolated surface which prediction accuracy grows when reaching central areas, we can actually say that in this areas found hot spots are accurate but we cannot be so sure about areas far from the centre or in which the presence of traffic counter is sporadic.

K-means demonstrated to be not suitable for cycling hot spots detection in Edinburgh's City area with our dataset, limits of K-means are intrinsic to the same methodology, as argued by

Smith and Bruce (2008, p. 13). We do not want to say that K-means it is not a good technique at all but the fact that requires the user to decide the number of hot spots does not surely satisfy our research requirements in which we did not actually have an expected number of clusters to find.

5. Criteria weighting methodology

An important component of the cost component of our network is undoubtedly distance and specifically how this criterion is compared against safety, the other one used in the determination of edge costs. Previous studies regarding the exploration of cyclists' preference between these two criteria in the choice of a cycling route indicate different results (Dill and Carr, 2003; Akar and Clifton, 2009) but what is made evident by all of them is that cyclists' route choices general criteria are very different from those of people travelling by car and cyclists are more prone to consider criteria that goes further than the sole time-distance criterion (Beheshtitabar et al., 2014). Comparable methodological research approaches are those of Hopkinson and Wardman (1996) and Winters et al. (2011), in former study 64% percent of 6286 people in Bradford UK judged as an incentive the improvement of safety measures while 55% declared to cycle because faster in comparison to other transport means. In the latter, shortness/quickness of cycling routes, intended as motivator, and the risk of injury from car-bike collisions, intended as a deterrent to cycling were ranked equally. Exploring these findings was important for us as it was not possible to base our weighting on the results of a survey, for a matter of time, and the choice of weights had to be partly based on arbitrary assumptions.

5.1 Pairwise comparison method

This method is used in multicriteria analysis with the aim of quantifying weights on the basis of assumptions, the weighing definition process followed the stages described in Malczewski (1999, p. 177) although the pairwise comparison method was first developed by Saati (1980). We decided to use pairwise comparison as this was the method that most suited our few criteria and was simple to develop (Malczewski, 1999, p. 190). The method employs an underlying scale from 1 to 9 in which the relative preference of each criterion is assessed in comparison to the other (table 1). We judged safety risk reduction to be moderately more important than distance so the comparison results in a score of 3 for the former.

In the second instance, we set the pairwise comparison matrix in which we actually compare our criteria assuming the reciprocity of criteria, this means that if safety scores 3 compared to distance, then distance will score $\frac{1}{3}$ compared to safety (table 2).

Table 1: scale for Pairwise Comparison

INTENSITY OF IMPORTANCE	DEFINITION
1	Equal importance
2	Equal to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong to very strong importance
6	Very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extreme importance

Table 2: Pairwise Comparison matrix

	SAFETY	LENGTH
SAFETY	1	3
LENGTH	$\frac{1}{3}$	1

To calculate weights, we first summed values in each column of the PC matrix, for safety column we will have 1 + 0.34 = 1.34 and for length 3 + 1 = 4; then we divided each element in the matrix for its column total as to obtain the normalised pairwise comparison matrix (table 3).

Table 3: normalised Pairwise Comparison matrix

	SAFETY	LENGTH
SAFETY	0.75	0.75
LENGTH	0.25	0.25

Weights are finally obtained computing the average of the normalised Pairwise Comparison matrix:

SAFETY = (0.75 + 0.75) / 2 = **0.75**

LENGTH = (0.25 + 0.25) / 2 = **0.25**

5.2 Estimation of consistency ratio

To assess weights comparison consistency we first had to multiply the weight times each correspondent column value in the Pairwise Comparison matrix in table 2 then dividing the value for the correspondent weight, so as to determine the weighted sum vector (table 4).

SAFETY = 1 x 0.75 + 3 x 0.25 = 1.5 / 0.75 = **2**

LENGTH = $\frac{1}{3}$ x 0.34 + 0.25 x 1 = 0.505 / 0.25 = **2.02**

Then we need to calculate lambda (λ), which simply is the average value of the weighted sum vector:

λ = (2 + 2.02) / 2 = **2.01**

Values of λ compared to the weighted sum vector describe Pairwise Comparison consistency. If the former is equal to the weighted sum vector *n*, then our Pairwise Comparison matrix can be considered consistent. $\lambda - n$ gives us a measure of the matrix inconsistency. The normalised value is called Consistency Index (CI).

CI = ($\lambda - n$) / (n – 1)

CI = (2.01 – 2) / (2 - 1) = **0.01**

Once found the CI we finally can calculate the CR, defined as CI / RI, where RI (the Random Index) is a standard value which represent a random inconsistency index for matrices with the comparison of different criteria (see Malczewski, 1999, p. 186). For two criteria RI = 0, thus being **CR** 0.01/0 = **0**, we can consider our Pairwise Comparison methodology as reasonably consistent, as CR > 0.10.

6. Dijkstra's and A* least cost path algorithm performance comparison

PgRouting offers the possibility to choose between these least cost path algorithms for single start and end points. We wanted to test their performance on the same network and with the same costs to finally utilise the one that best succeeded at reducing both costs and path length. We do not think it is necessary to make here a description of the algorithms, this information has been extensively debated elsewhere and theoretical foundations can be found in Dijkstra (1959) and Hart et al. (1968). We do want instead highlight what differentiates them in terms of working and suitability.

A* executes a heuristic on all nodes in the network before performing the least cost path searching, this means it calculates the cost which is necessary to undertake for each node in the network to get there from the start node (called G) and to get from each node to the end node (called H) the sum of G + H is called F and it is the cost which is taken into account for the execution of the subsequent searching algorithm. In Dijkstra we have a search of the least cost path on the basis of costs given to edges, those are summed to nodes at each step of their choice and the subsequent node with the least cost is chosen until the end node is reached, there is no prior knowledge of network general costs, and for this reason for each node, all least cost paths are searched.

This difference reflects the computation time of the least cost path as noticed in Peng et al. (2012) and Cho et al. (2013) which can be extremely reduced using A* in very large networks, but this is not our case. What we wanted to assess instead, and this has not been quite explored in the current literature, is if on their use might depend the least cost/distance outcome in a small network, as the one used in our study area.

6.1 Test methodology

We randomly generated 20 paths within the network of our study area and for each of them we calculated their length and total cost to get from the start to the end point both for the least cost path generated with Dijkstra's and A* algorithm. We calculated the average distance difference for all attempts both expressed in absolute value and percentage (see table 4).

6.2 Test's results discussion

As for length, in 10 attempts out of 20 Dijkstra outperformed A*, in 4 cases we saw the opposite and in the remaining 4, length and also cost, were the same. In the first cases the average difference was 1079.33 metres, an average reduction of 6%. In the second cases the average length difference was 90.73 metres, an average reduction of 6%. When we refer our comparison to costs, we can see a clear advantage of Dijkstra (16 times) with an average cost reduction of 0.0063, approximately 6% better than A*.

The test on our network showed Dijkstra's algorithm better performances in both distance and cost for shortest path. The prevalence might be explained by the execution of the prior heuristic in A* that allows that improve time performances in larger and denser networks (Zeng and Chucrh, 2009), but this is not our case. Our study area network is small and relatively dense, our test highlight how Dijkstra's algorithm still is more efficient in these cases, as also noticed by Cherkassky et al. (1996). Shortest path computation time was excluded from evaluation in our test, the consideration of this criterion would have led to more informed conclusions or different results for further studies of the application of shortest paths algorithms in small networks.

Table 4: Dijkstra’s and A* algorithms comparison, summarising table

ATTEMPT	ALGORITHM	ID START	ID END	LENGTH m	TOTAL COST	LEAST LENGTH	GTH DIFFERENCE me	LENGTH % DIFFERENCE	LEAST COST	COST DIFFERENCE	COST % DIFFERENCE
	DIJKSTRA	1177	659	6517.31	0.042975	A*	-93.747	-1.459423687	DIJKSTRA	-0.002351	-5.186868464
1	**A***	1177	659	6423.563	0.045326						
	DIJKSTRA	4880	19856	15738.83	0.1010056	A*	-56.09	-0.357654338	DIJKSTRA	-0.0028594	-2.752996678
2	**A***	4880	19856	15682.74	0.103865						
	DIJKSTRA	18442	3220	15757.6	0.106714	DIJKSTRA	-408.9	-2.529304426	DIJKSTRA	-0.000275	-0.25703577
3	**A***	18442	3220	16166.5	0.106989						
	DIJKSTRA	1328	8065	5450.148	0.034862591	SAME	0	0	SAME	0	0
4	**A***	1328	8065	5450.149	0.034863						
	DIJKSTRA	179	1351	5006.74	0.03338029	SAME	0	0	SAME	0	0
5	**A***	179	1351	5006.74	0.033803						
	DIJKSTRA	22572	43916	10914.07	0.06733365	SAME	0	0	SAME	0	0
6	**A***	22572	43916	10914.07	0.067334						
	DIJKSTRA	28351	22572	14570.68	0.08178458	A*	-51.64	-0.353158733	DIJKSTRA	-0.00014642	-0.178711355
7	**A***	28351	22572	14622.32	0.081931						
	DIJKSTRA	10670	21937	23593.97	0.1543155	DIJKSTRA	-1367.13	-5.477042278	DIJKSTRA	-0.0079905	-4.923108203
8	**A***	10670	21937	24961.1	0.162306						
	DIJKSTRA	8002	32530	7446.99	0.0493493	DIJKSTRA	-439.178	-5.568965815	DIJKSTRA	-0.0017427	-3.410905817
9	**A***	8002	32530	7886.168	0.051092						
	DIJKSTRA	19548	711	9734.59	0.064206	DIJKSTRA	-156.38	-1.581038058	DIJKSTRA	-0.001553	-2.361653918
10	**A***	19548	711	9890.97	0.065759						
	DIJKSTRA	11913	19074	36250.98	0.211443972	DIJKSTRA	-1950.032	-5.104660578	DIJKSTRA	-0.023240028	-9.902689574
11	**A***	11913	19074	38201.012	0.234684						
	DIJKSTRA	10116	9873	2003.0133	0.012001805	DIJKSTRA	-263.9767	-11.64436985	DIJKSTRA	-0.002538195	-17.4566348
12	**A***	10116	9873	2266.99	0.01454						
	DIJKSTRA	25501	24534	19997.55	0.140396772	A*	-55.856	-0.279314216	DIJKSTRA	-0.000591118	-0.419268917
13	**A***	25501	24534	19941.694	0.14098789						
	DIJKSTRA	3392	3789	15111.02	0.094084004	DIJKSTRA	-1625.5	-9.712293834	DIJKSTRA	-0.011146996	-10.59288233
14	**A***	3392	3789	16736.52	0.105231						
	DIJKSTRA	42619	28727	14763.4	0.0933239	DIJKSTRA	-2104.78	-12.47781326	DIJKSTRA	-0.0131111	-12.3184103
15	**A***	42619	28727	16868.18	0.106435						
	DIJKSTRA	5039	31727	13203.07	0.081354208	A*	-168.514	-1.27632437	DIJKSTRA	-0.002973792	-3.526458116
16	**A***	5039	31727	13034.556	0.084328						
	DIJKSTRA	44841	29734	7304.96	0.045054	SAME	0	0	SAME	0	0
17	**A***	44841	29734	7304.96	0.045054						
	DIJKSTRA	2224	3307	10489.16	0.06244669	A*	-118.59	-1.130595777	DIJKSTRA	-0.00479731	-7.134182975
18	**A***	2224	3307	10370.57	0.067244						
	DIJKSTRA	26668	18882	33392.65	0.1932686	DIJKSTRA	-1383.5	-3.978301221	DIJKSTRA	-0.0203494	-9.5260699
19	**A***	26668	18882	34776.15	0.213618						
	DIJKSTRA	14078	16023	22256.44	0.135766642	DIJKSTRA	-1094.02	-4.685218193	DIJKSTRA	-0.004151358	-2.966993603
20	**A***	14078	16023	23350.46	0.139918						

7. Web-GIS Service Survey Results

We will include in this part the remaining results of the final survey on the use of the web service. The survey included also textual answers and comments on purposes and usability of the web service. As the testing part and development were carried out at the same time some suggestions were included as improvements. Moreover, textual comments are were very useful to understand more precisely which were the factors that determined the exclusion of the safe route planner, so as to identify the flaws of our model and to understand on which areas further development would need to focus on.

The first question was to assess whether the use frequency of bicycle between the two groups of users that we chose. 90% of regular cyclists declared to cycle every day, a part one who cycles regularly once week. In the non-regular cyclists group 80% of respondents never cycles while the remaining is split between a person who cycles just in the weekends and another who cycles no more than four days a week, considering the seven days week, these two cyclists declared to belong to the second group as they cycle just occasionally . Results are pretty significant and findings can be based on consistent basis as it is possible to clearly separate two groups characteristics according to vary different declared cycling patterns.

The second question was made to understand how aware cyclists were already of the most dangerous points in our study area, the conception of danger is here completely subjective as we did not want to bias our respondents in advance and see whether our service could be effective in generating new spatial awareness in users with different accidents concentration visualisation. The survey shows that experienced cyclists are generally more aware of dangers than non-experienced, we could then expect different answers when asking them if GIS is able to locate areas they though, or might not have thought, as dangerous.

Question three and four were aimed at testing two related things:

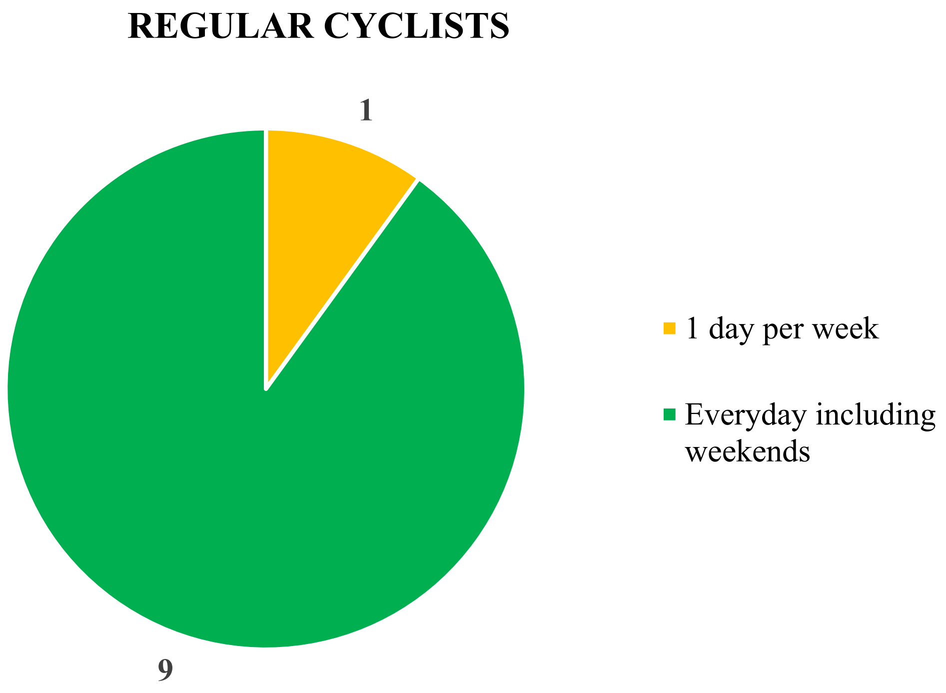
1. The exactness of the service at locating accidents for whom already had a personal idea of their location.

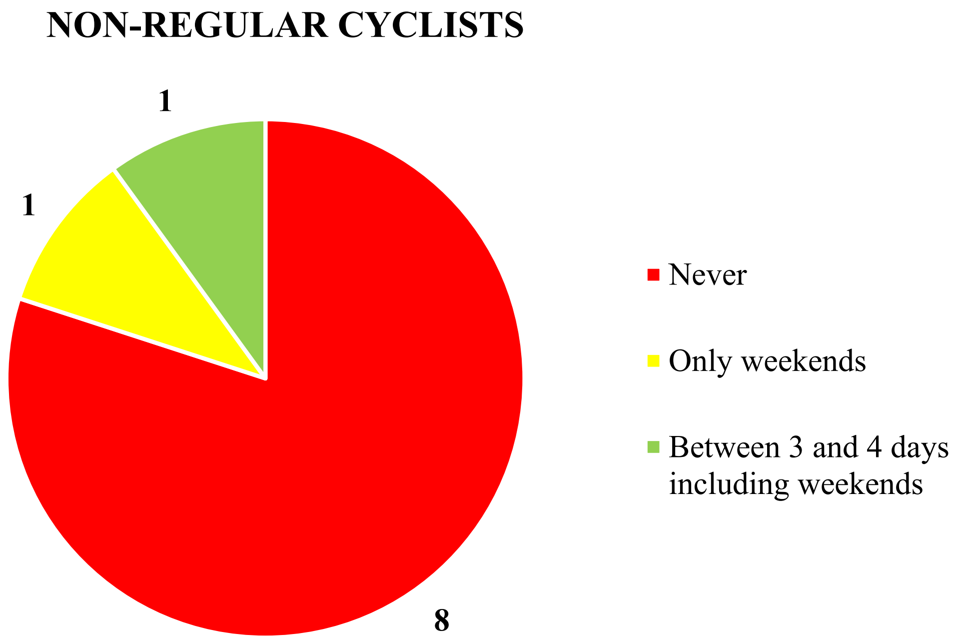
We generally have positive feedbacks from both groups, all respondents agree that our web service located accidents where expected in users who have a prior personal knowledge of accidents location.

Finally, question 9 in which we have seen confirmed much of the limitations of both web services that were already made evident by previous comments. One flaws that is possible to find in both systems, according to what we can see in survey results, is the excessive length of the quietest and safest route in both cases. Another general element which is worth to highlight is one response from a non-regular cyclist who says that in both cases web services were not effective in conveying “quietness” and “safety”. Although if one response cannot be identified as significant in the sample, that was already small, it could be indicative of a non-complete attainment in the aim of both systems. A larger sample and more exploratory questions might highlight different approaches in regarding the whole question of the communication methods and platforms. Suggestions might point out that alternative tools and visualisations could reach a greater number of individuals.

Qestion n. 1:

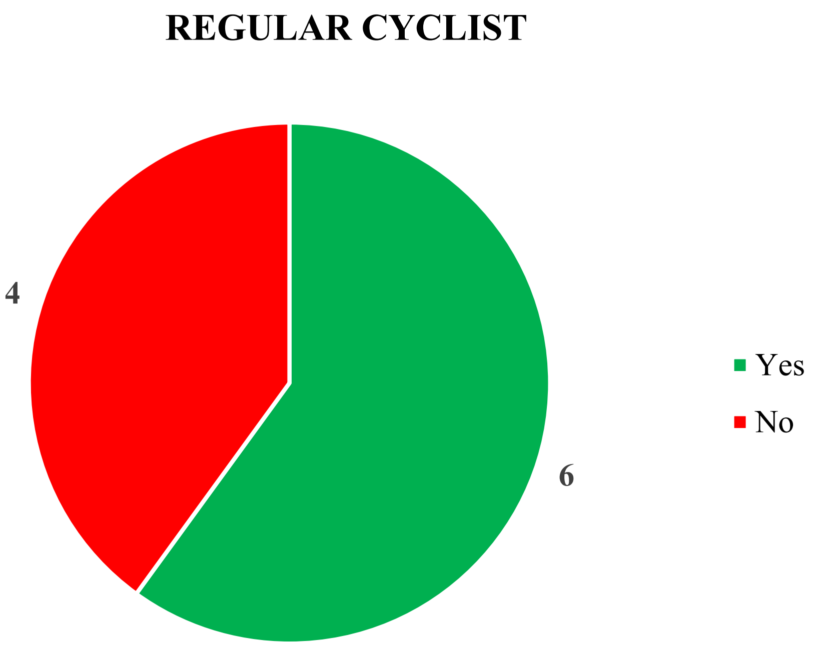
In a week of your everyday life, how often do you cycle?

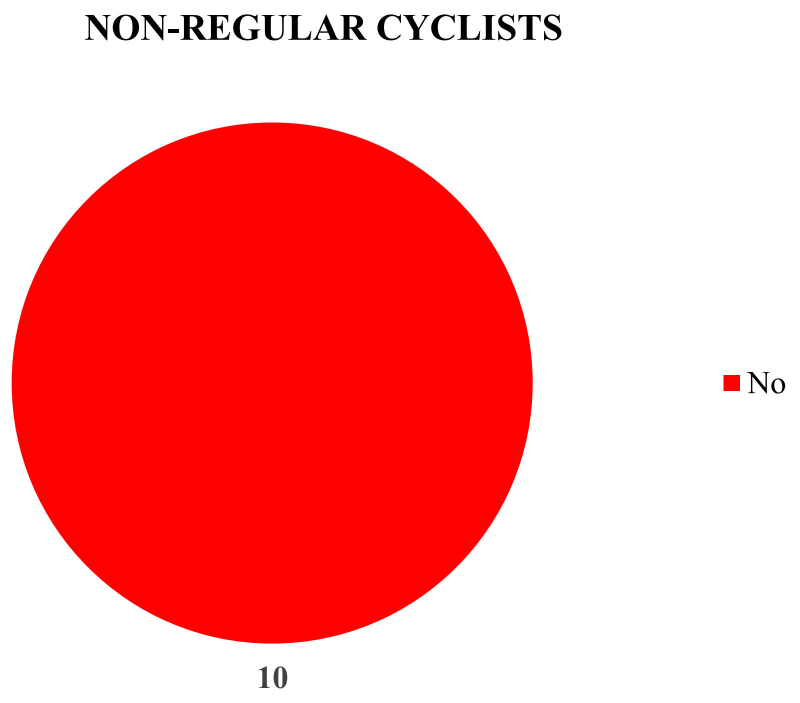




Question n. 2:

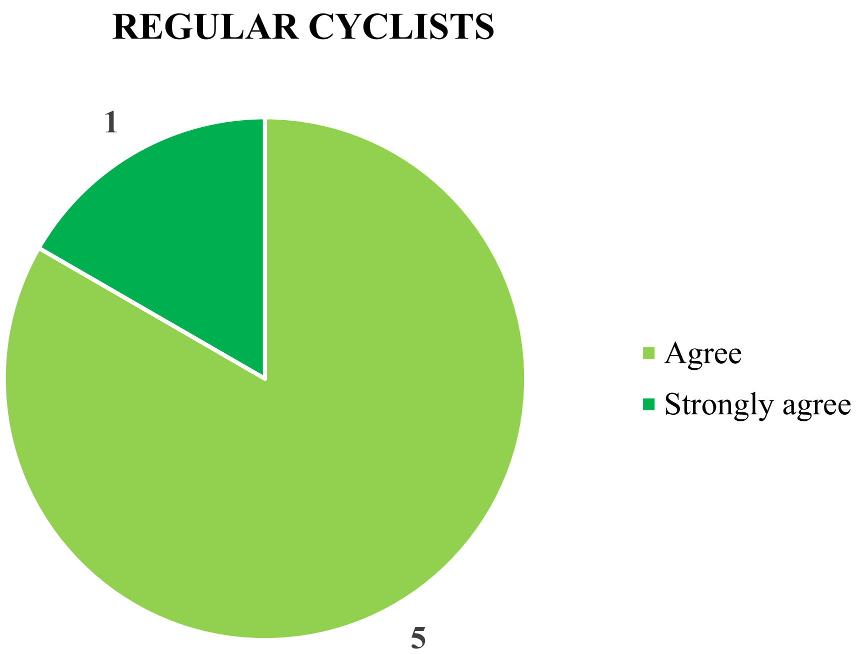
According to your conception of risk and your daily routine shifts, are you aware of the location of the riskiest points, in terms of cycling incidence, in the area of the City of Edinburgh?

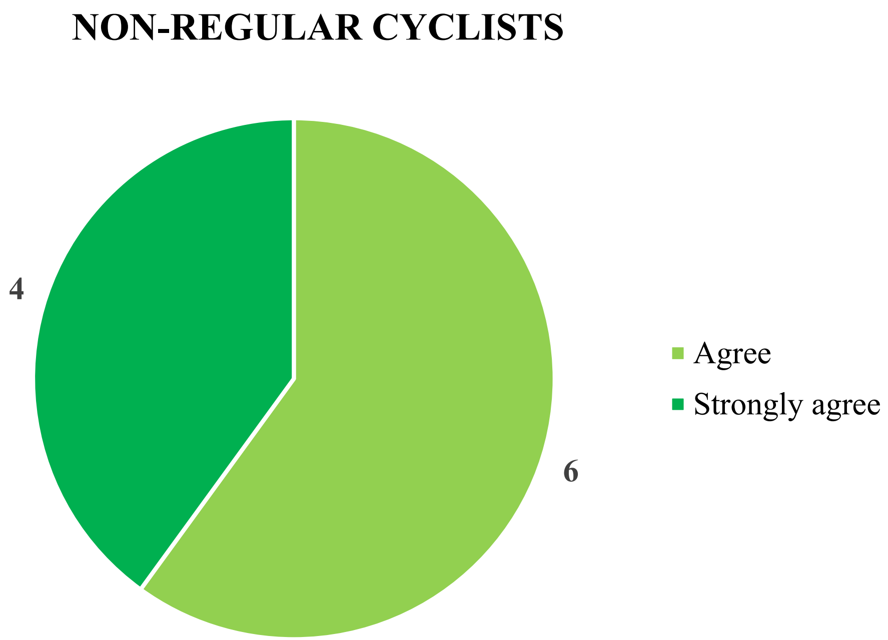




Question n. 4:

Answer this question only if you answered "No" to question 2, "I am now more aware of the location of cycling accidents in the area of the City of Edinburgh". How much do you agree with this sentence?





Question n. 9:

In case you did not respond “No preference” could you please briefly explain some reasons of your preference?

Answers by regular cyclists group:

CycleStreets was easier to use.

The suitability of the routes suggested by the web service are dependent on the journey. In two cases I would use those suggested but in the other I wouldn’t.

In the first route the web service was better and in the other two CycleStreets, it is evident that the web service routes avoid accidents though.

Answers by non-regular cyclists group:

The routes suggested by the web service seem to be longer.

I think safety is very important when cycling and it avoids the busiest roads, but I can’t tell which route I would choose as I should try them first.

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Appendix
I
Main tables/views creation

Accidents data 2005-2012:

```
CREATE TABLE cycling_accidents_1915_osgb
(
  acc_id character varying(13) NOT NULL,
  osgb_east integer,
  osgb_north integer,
  longt numeric(7,6),
  lat numeric(8,6),
  police_force smallint,
  acc_severity smallint,
  n_vei smallint,
  n_cas smallint,
  dat date,
  week_day smallint,
  tim time without time zone,
  loc_auth_d smallint,
  loc_auth_h character varying(9),
  fst_road_class smallint,
  fst_road_number smallint,
  road_type smallint,
  speed_limit smallint,
  junct_det smallint,
  junct_cont smallint,
  scn_road_class smallint,
  scn_road_num smallint,
  ped_cross_hum smallint,
  ped_cross_phy smallint,
  light smallint,
  weather smallint,
  surface smallint,
  spec_site_cond smallint,
  carr_hazards smallint,
  urb_rur smallint,
  officer_att smallint,
  lsoa_acc_loc smallint,
  vei_type smallint,
  the_geom geometry,
  CONSTRAINT cycling_accidents_1915_osgb_pkey PRIMARY KEY (acc_id),
  CONSTRAINT enforce_dimd_the_geom CHECK (st_ndims(the_geom) = 2),
  CONSTRAINT enforce_geotype_geom CHECK (geometrytype(the_geom) =
'POINT'::text OR the_geom IS NULL),
--For a reason of brevity I will include here just the OSGB geometry SRID
creation type, because in WGS 84 the only thing that would change is the
SRID code (4326)
  CONSTRAINT enforce_srid_the_geom CHECK (st_srid(the_geom) = 27700)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE cycling_accidents_1915_osgb
  OWNER TO postgres;
```

Vehicles data 2005-2012:

```
CREATE TABLE veichles0512
(
  id serial NOT NULL,
  acc_id character varying(13),
  vei_ref smallint,
  vei_type smallint,
  tow_art smallint,
  manovra smallint,
  vei_loc smallint,
  junct_loc smallint,
  skid_over smallint,
  obj_on_carr smallint,
  vei_leave_carr smallint,
  obj_of_carr smallint,
  fst_impact_pt smallint,
  left_drive smallint,
  purpose smallint,
  driver_sex smallint,
  driver_age_band smallint,
  engine_cc integer,
  prop_code smallint,
  vei_age smallint,
  dri_imd_decile smallint,
  dri_home_area smallint,
  CONSTRAINT id_pkey PRIMARY KEY (id)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE veichles0512
  OWNER TO postgres;
```

Casualties data 2005-2012:

```
CREATE TABLE casualties0512
(
  id serial NOT NULL,
  acc_id character varying(13),
  vei_ref smallint,
  cas_ref smallint,
  cas_class smallint,
  cas_sex smallint,
  cas_age_band smallint,
  cas_severity smallint,
  ped_loc smallint,
  ped_mov smallint,
  car_pass smallint,
  bus_pass smallint,
  ped_maint smallint,
  cas_type smallint,
  cas_home_area smallint,
  CONSTRAINT veichles0512_pkey PRIMARY KEY (id)
)
```

```
WITH (
  OIDS=FALSE
);
ALTER TABLE casualties0512
  OWNER TO postgres;
```

View containing traffic counters AADF data 2005-2012:

```
CREATE OR REPLACE VIEW counters_0512 AS
 SELECT counters_edi_0510.cp,
    counters_edi_0510.region,
    counters_edi_0510.local_authority,
    counters_edi_0510.road_category,
    counters_edi_0510.road,
    counters_edi_0510.osgb_east,
    counters_edi_0510.osgb_north,
    counters_edi_0510.start_junct,
    counters_edi_0510.end_junct,
    counters_edi_0510.link_leng_km,
    counters_edi_0510.link_leng_m,
    counters_edi_0510.n_cycles_2005,
    counters_edi_0510.n_cycles_2006,
    counters_edi_0510.n_cycles_2007,
    counters_edi_0510.n_cycles_2008,
    counters_edi_0510.n_cycles_2009,
    counters_edi_0510.n_cycles_2010,
    counters_edi_1112.n_cycles_2011,
    counters_edi_1112.n_cycles_2012,
    round(((counters_edi_0510.n_cycles_2005 +
counters_edi_0510.n_cycles_2006 + counters_edi_0510.n_cycles_2007 +
counters_edi_0510.n_cycles_2008 + counters_edi_0510.n_cycles_2009 +
counters_edi_0510.n_cycles_2010 + counters_edi_1112.n_cycles_2011 +
counters_edi_1112.n_cycles_2012) / 8)::numeric, 0) AS avg,
    counters_edi_0510.the_geom
   FROM counters_edi_0510,
    counters_edi_1112
  WHERE counters_edi_1112.cp = counters_edi_0510.cp
  GROUP BY counters_edi_0510.cp, counters_edi_1112.n_cycles_2011,
counters_edi_1112.n_cycles_2012;

ALTER TABLE counters_0512
  OWNER TO postgres;
```

Appendix
II
Textual definitions tables creation queries and structure

1. casualty age band:

```
CREATE TABLE d_age_band
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_driver_age_band_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_age_band
  OWNER TO postgres;

1;"0 - 5"
2;"6 - 10"
3;"11 - 15"
4;"16 - 20"
5;"21 - 25"
6;"26 - 35"
7;"36 - 45"
8;"46 - 55"
9;"56 - 65"
10;"66 - 75"
11;"Over 75"
;""
```

2. Attendant circumstances for bus passenger casualty:

```
CREATE TABLE d_bus_pass
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_bus_pass_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_bus_pass
  OWNER TO postgres;

-1;"Data missing or out of range"
0;"Not a bus or coach passenger"
1;"Boarding"
2;"Alighting"
3;"Standing passenger"
4;"Seated passenger"
;""
```

3. Attendant circumstances for car passenger casualty:

```
CREATE TABLE d_car_pass
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_car_pass_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_car_pass
  OWNER TO postgres;

-1;"Data missing or out of range"
0;"Not car passenger"
1;"Front seat passenger"
2;"Rear seat passenger"
;""
```

4. Carriageway hazards:

```
CREATE TABLE d_carr_hazards
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_carr_hazards_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_carr_hazards
  OWNER TO postgres;

-1;"Data missing or out of range"
0;"None"
1;"Vehicle load on road"
2;"Other object on road"
3;"Previous accident"
4;"Dog on road"
5;"Other animal on road"
6;"Pedestrian in carriageway - not injured"
7;"Any animal in carriageway (except ridden horse)"
;""
```

5. Casualty class:

```
CREATE TABLE d_cas_class
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_cas_class_pkey PRIMARY KEY (code)
)
WITH (
```

```
  OIDS=FALSE
);
ALTER TABLE d_cas_class
  OWNER TO postgres;

1;"Driver or rider"
2;"Passenger"
3;"Pedestrian"
;""
```

6. Casualty type:

```
CREATE TABLE d_cas_type
(
  code smallint NOT NULL,
  label character varying(100),
  CONSTRAINT d_cas_type_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_cas_type
  OWNER TO postgres;

0;"Pedestrian"
1;"Cyclist"
2;"Motorcycle 50cc and under rider or passenger"
3;"Motorcycle 125cc and under rider or passenger"
4;"Motorcycle over 125cc and up to 500cc rider or  passenger"
5;"Motorcycle over 500cc rider or passenger"
8;"Taxi/Private hire car occupant"
9;"Car occupant"
10;"Minibus (8 - 16 passenger seats) occupant"
11;"Bus or coach occupant (17 or more pass seats)"
16;"Horse rider"
17;"gricultural vehicle occupant"
18;"Tram occupant"
19;"Van / Goods vehicle (3.5 tonnes mgw or under) occupant"
20;"Goods vehicle (over 3.5t. and under 7.5t.) occupant"
21;"Goods vehicle (7.5 tonnes mgw and over) occupant"
22;"Mobility scooter rider"
23;"Electric motorcycle rider or passenger"
90;"Other vehicle occupant"
97;"Motorcycle - unknown cc rider or passenger"
98;"Goods vehicle (unknown weight) occupant"
103;"Motorcycle - Scooter rider or passenger"
104;"Motorcycle rider or passenger"
105;"Motorcycle - Combination rider or passenger"
106;"Motorcycle over 125cc rider or passenger"
108;"Taxi (excluding private hire cars) occupant"
109;"Car occupant (including private hire cars)"
110;"Minibus/Motor caravan occupant"
113;"Goods vehicle (over 3.5 tonnes) occupant"
;""
```

7. Day of the week:

```
CREATE TABLE d_day_of_week
(
  code smallint NOT NULL,
  label character varying,
  CONSTRAINT day_week_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_day_of_week
  OWNER TO postgres;

1;"Sunday"
2;"Monday"
3;"Tuesday"
4;"Wednesday"
5;"Thursday"
6;"Friday"
7;"Saturday"
;""
```

8. First impact point:

```
CREATE TABLE d_fst_impact_pt
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_fst_impact_pt_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_fst_impact_pt
  OWNER TO postgres;

-1;"Data missing or out of range"
0;"Did not impact"
1;"Front"
2;"Back"
3;"Offside"
4;"Nearside"
;""
```

9. First road class:

```
CREATE TABLE d_fst_road_class
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT fst_road_class_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
```

```
);
ALTER TABLE d_fst_road_class
  OWNER TO postgres;

1;"Motorway"
2;"A(M)"
3;"A"
4;"B"
5;"C"
6;"Unclassified"
;""
```

10. Home Area Type:

```
CREATE TABLE d_home_area
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_home_area_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_home_area
  OWNER TO postgres;

-1;"Data missing or out of range"
1;"Urban area"
2;"Small town"
3;"Rural"
;""
```

11. Junction traffic control:

```
CREATE TABLE d_junct_con
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_junct_con_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_junct_con
  OWNER TO postgres;

-1;"Data missing or out of range"
0;"Not at junction or within 20 metres"
1;"Authorised person"
2;"Auto traffic signal"
3;"Stop sign"
4;"Give way or uncontrolled"
;""
```

12. Junction details:

```
CREATE TABLE d_junct_det
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_junct_det_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_junct_det
  OWNER TO postgres;

-1;"Data missing or out of range"
0;"Not at junction or within 20 metres"
1;"Roundabout"
2;"Mini-roundabout"
3;"T or staggered junction"
5;"Slip road"
6;"Crossroads"
7;"More than 4 arms (not roundabout)"
8;"Private drive or entrance"
9;"Other junction"
;""
```

13. Vehicle location respect to junction:

```
CREATE TABLE d_junct_loc
(
  code smallint NOT NULL,
  label character varying(100),
  CONSTRAINT d_junct_loc_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_junct_loc
  OWNER TO postgres;
-1;"Data missing or out of range"
0;"Not at or within 20 metres of junction"
1;"Approaching junction or waiting/parked at junction approach"
2;"Cleared junction or waiting/parked at junction exit"
3;"Leaving roundabout"
4;"Entering roundabout"
5;"Leaving main road"
6;"Entering main road"
7;"Entering from slip road"
8;"Mid Junction - on roundabout or on main road"
;""
```

14. Left drive vehicle:

```
CREATE TABLE d_left_drive
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_left_drive_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_left_drive
  OWNER TO postgres;

-1;"Data missing or out of range"
1;"No"
2;"Yes"
;""
```

15. Light conditions:

```
CREATE TABLE d_light
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_light_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_light
  OWNER TO postgres;

-1;"Data missing or out of range"
1;"Daylight"
4;"Darkness - lights lit"
5;"Darkness - lights unlit"
6;"Darkness - no lighting"
7;"Darkness - lighting unknown"
;""
```

16. Manoeuvre (the table was called with the correspondent Italian term "manovra" for simplicity):

```
CREATE TABLE d_manovra
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_manovra_pkey PRIMARY KEY (code)
)
```

```
WITH (
  OIDS=FALSE
);
ALTER TABLE d_manovra
  OWNER TO postgres;

-1;"Data missing or out of range"
1;"Reversing"
2;"Parked"
3;"Waiting to go - held up"
4;"Slowing or stopping"
5;"Moving off"
6;"U-turn"
7;"Turning left"
8;"Waiting to turn left"
9;"Turning right"
10;"Waiting to turn right"
11;"Changing lane to left"
12;"Changing lane to right"
13;"Overtaking moving vehicle - offside"
14;"Overtaking static vehicle - offside"
15;"Overtaking - nearside"
16;"Going ahead left-hand bend"
17;"Going ahead right-hand bend"
18;"Going ahead other"
;""
```

17. Vehicle hit an object off the carriageway:

```
CREATE TABLE d_obj_of_carr
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_obj_of_carr_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_obj_of_carr
  OWNER TO postgres;

-1;"Data missing or out of range"
0;"None"
1;"Road sign or traffic signal"
2;"Lamp post"
3;"Telegraph or electricity pole"
4;"Tree"
5;"Bus stop or bus shelter"
6;"Central crash barrier"
7;"Near/Offside crash barrier"
8;"Submerged in water"
9;"Entered ditch"
10;"Other permanent object"
11;"Wall or fence"
```

```
;""
```

18. Presence of an object on the carriageway:

```
CREATE TABLE d_obj_on_carr
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_obj_on_carr_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_obj_on_carr
  OWNER TO postgres;

-1;"Data missing or out of range"
0;"None"
1;"Previous accident"
2;"Road works"
3;"Parked vehicle"
5;"Bridge (roof)"
6;"Bridge (side)"
7;"Bollard or refuge"
8;"Open door of vehicle"
9;"Central island of roundabout"
10;"Kerb"
11;"Other object"
12;"Any animal (except ridden horse)"
;""
```

19. Police officer attended site of accident:

```
CREATE TABLE d_officer_att
(
  code smallint NOT NULL,
  label character varying(100),
  CONSTRAINT d_officer_att_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_officer_att
  OWNER TO postgres;
```

```
1;"Yes"
2;"No"
3;"No - accident was reported using a self completion  form (self rep only)"
;""
```

20. Human pedestrian crossing control:

```
CREATE TABLE d_ped_cross_hum
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_ped_cross_hum_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_ped_cross_hum
  OWNER TO postgres;

-1;"Data missing or out of range"
0;"None within 50 metres "
1;"Control by school crossing patrol"
2;"Control by other authorised person"
;""
```

21. Physical pedestrian crossing control:

```
CREATE TABLE d_ped_cross_phy
(
  code smallint NOT NULL,
  label character varying(100),
  CONSTRAINT d_ped_cross_phy_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_ped_cross_phy
  OWNER TO postgres;

-1;"Data missing or out of range"
0;"No physical crossing facilities within 50 metres"
1;"Zebra"
4;"Pelican puffin toucan or similar non-junction pedestrian light crossing"
5;"Pedestrian phase at traffic signal junction"
7;"Footbridge or subway"
8;"Central refuge"
;""
```

22. Pedestrian location:

```
CREATE TABLE d_ped_loc
(
  code smallint NOT NULL,
  label character varying(150),
  CONSTRAINT d_ped_loc_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_ped_loc
  OWNER TO postgres;


-1;"Data missing or out of range"
0;"Not a Pedestrian"
1;"Crossing on pedestrian crossing facility"
2;"Crossing in zig-zag approach lines"
3;"Crossing in zig-zag exit lines"
4;"Crossing elsewhere within 50m. of pedestrian crossing"
5;"In carriageway.crossing elsewhere"
6;"On footway or verge"
7;"On refuge.central island or central reservation"
8;"In centre of carriageway - not on refuge.island or central
reservation"
9;"In carriageway.not crossing"
10;"Unknown or other"
;""
```

23. pedestrian crossing facility under maintenance:

```
CREATE TABLE d_ped_maint
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_ped_maint_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_ped_maint
  OWNER TO postgres;


-1;"Data missing or out of range"
0;"No / Not applicable"
1;"Yes"
2;"Not Known"
```

```
;""
```

24. Pedestrian movement:

```
CREATE TABLE d_ped_mov
(
  code smallint NOT NULL,
  label character varying(150),
  CONSTRAINT d_ped_mov_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_ped_mov
  OWNER TO postgres;

-1;"Data missing or out of range"
0;"Not a Pedestrian"
1;"Crossing from driver's nearside"
2;"Crossing from nearside - masked by parked or stationary vehicle"
3;"Crossing from driver's offside"
4;"Crossing from offside - masked by  parked or stationary vehicle"
5;"In carriageway. stationary - not crossing  (standing or playing)"
6;"In carriageway. stationary - not crossing  (standing or playing) -
masked by parked or stationary vehicle"
7;"Walking along in carriageway. facing traffic"
8;"Walking along in carriageway. back to traffic"
9;"Unknown or other"
;""
```

25. Vehicle propulsion code:

```
CREATE TABLE d_prop_code
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_prop_code_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_prop_code
  OWNER TO postgres;


1;"Petrol"
2;"Heavy oil"
3;"Electric"
4;"Steam"
5;"Gas"
6;"Petrol/Gas (LPG)"
```

```
7;"Gas/Bi-fuel"
8;"Hybrid electric"
9;"Fuel cells"
10;"New fuel technology"
;""
```

26. Purpose of journey:

```
CREATE TABLE d_purpose
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_purpose_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_purpose
  OWNER TO postgres;

-1;"Data missing or out of range"
1;"Journey as part of work"
2;"Commuting to/from work"
3;"Taking pupil to/from school"
4;"Pupil riding to/from school"
5;"Other"
6;"Not known"
15;"Other/Not known (2005-10)"
;""
```

27. Road type:

```
CREATE TABLE d_road_type
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_road_type_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_road_type
  OWNER TO postgres;

-1;"Data missing or out of range"
1;"Roundabout"
2;"One way street"
3;"Dual carriageway"
6;"Single carriageway"
7;"Slip road"
9;"Unknown"
12;"One way street/Slip road"
```

```
;""
```

28. Second road class:

```
CREATE TABLE d_scn_road_class
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT scn_road_class_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_scn_road_class
  OWNER TO postgres;

-1;"Not at junction or within 20 metres"
1;"Motorway"
2;"A(M)"
3;"A"
4;"B"
5;"C"
6;"Unclassified"
;""
```

29. Accidents/casualty severity:

```
CREATE TABLE d_severity
(
  code smallint NOT NULL,
  label character varying,
  CONSTRAINT p_key PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_severity
  OWNER TO postgres;

1;"Fatal"
2;"Serious"
3;"Slight"
;""
```

30. Casualty sex:

```
CREATE TABLE d_sex
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_driver_sex_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_sex
  OWNER TO postgres;


-1;"Data missing or out of range"
1;"Male"
2;"Female"
3;"Not known"
;""
```

31. Vehicle skidding or overturning:

```
CREATE TABLE d_skid_over
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_skid_over_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_skid_over
  OWNER TO postgres;

-1;"Data missing or out of range"
0;"None"
1;"Skidded"
2;"Skidded and overturned"
3;"Jackknifed"
4;"Jackknifed and overturned"
5;"Overturned"
;""
```

32. Special conditions on accident site:

```
CREATE TABLE d_spec_site_cond
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_spec_site_cond_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
```

```
);
ALTER TABLE d_spec_site_cond
  OWNER TO postgres;

-1;"Data missing or out of range"
0;"None"
1;"Auto traffic signal - out"
2;"Auto signal part defective"
3;"Road sign or marking defective or obscured"
4;"Roadworks"
5;"Road surface defective"
6;"Oil or diesel"
7;"Mud"
;""
```

33. Type of road surface:

```
CREATE TABLE d_surface
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_surface_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_surface
  OWNER TO postgres;

-1;"Data missing or out of range"
1;"Dry"
2;"Wet or damp"
3;"Snow"
4;"Frost or ice"
5;"Flood over 3cm. deep"
6;"Oil or diesel"
7;"Mud"
;""
```

34. Vehicle towing or articulation:

```
CREATE TABLE d_tow_art
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_tow_art_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
```

```
);
ALTER TABLE d_tow_art
  OWNER TO postgres;

-1;"Data missing or out of range"
0;"No tow/articulation"
1;"Articulated vehicle"
2;"Double or multiple trailer"
3;"Caravan"
4;"Single trailer"
5;"Other tow"
;""
```

35. Urban or Rural context of the accident:

```
CREATE TABLE d_urb_rur
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_urb_rur_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_urb_rur
  OWNER TO postgres;

1;"Urban"
2;"Rural"
3;"Unallocated"
;""
```

36. Did vehicle leave carriageway?:

```
CREATE TABLE d_vei_leave_carr
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_vei_leave_carr_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_vei_leave_carr
  OWNER TO postgres;

-1;"Data missing or out of range"
0;"Did not leave carriageway"
1;"Nearside"
2;"Nearside and rebounded"
3;"Straight ahead at junction"
4;"Offside on to central reservation"
```

```
5;"Offside on to centrl res + rebounded"
6;"Offside - crossed central reservation"
7;"Offside"
8;"Offside and rebounded"
;""
```

37.Vehicle location:

```
CREATE TABLE d_vei_loc
(
  code smallint NOT NULL,
  label character varying(100),
  CONSTRAINT d_vei_loc_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_vei_loc
  OWNER TO postgres;


-1;"Data missing or out of range"
0;"On main c'way - not in restricted lane"
1;"Tram/Light rail track"
2;"Bus lane"
3;"Busway (including guided busway)"
4;"Cycle lane (on main carriageway)"
5;"Cycleway or shared use footway (not part of  main carriageway)"
6;"On lay-by or hard shoulder"
7;"Entering lay-by or hard shoulder"
8;"Leaving lay-by or hard shoulder"
9;"Footway (pavement)"
10;"Not on carriageway"
;""
```

38. Vehicle type:

```
CREATE TABLE d_vei_type
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_vei_type_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_vei_type
  OWNER TO postgres;

-1;"Data missing or out of range"
1;"Pedal cycle"
2;"Motorcycle 50cc and under"
```

```
3;"Motorcycle 125cc and under"
4;"Motorcycle over 125cc and up to 500cc"
5;"Motorcycle over 500cc"
8;"Taxi/Private hire car"
9;"Car"
10;"Minibus (8 - 16 passenger seats)"
11;"Bus or coach (17 or more pass seats)"
16;"Ridden horse"
17;"Agricultural vehicle"
18;"Tram"
19;"Van / Goods 3.5 tonnes mgw or under"
20;"Goods over 3.5t. and under 7.5t"
21;"Goods 7.5 tonnes mgw and over"
22;"Mobility scooter"
23;"Electric motorcycle"
90;"Other vehicle"
97;"Motorcycle - unknown cc"
98;"Goods vehicle - unknown weight"
103;"Motorcycle - Scooter"
104;"Motorcycle"
105;"Motorcycle - Combination"
106;"Motorcycle over 125cc"
108;"Taxi (excluding private hire cars)"
109;"Car (including private hire cars)"
110;"Minibus/Motor caravan"
113;"Goods vehicle over 3.5 tonnes"
;""
```

39. Weather conditions:

```
CREATE TABLE d_weather
(
  code smallint NOT NULL,
  label character varying(50),
  CONSTRAINT d_weather_pkey PRIMARY KEY (code)
)
WITH (
  OIDS=FALSE
);
ALTER TABLE d_weather
  OWNER TO postgres;

-1;"Data missing or out of range"
1;"Fine no high winds"
2;"Raining no high winds"
3;"Snowing no high winds"
4;"Fine + high winds"
5;"Raining + high winds"
6;"Snowing + high winds"
7;"Fog or mist"
8;"Other"
9;"Unknown"
;""
```

Appendix
III

Accidents – Vehicles – Casualties
view creation

```
CREATE OR REPLACE VIEW acc_vei_cas AS
 SELECT row_number() OVER () AS id,
    cycling_accidents_1915_osgb.acc_id AS id_accident,
    cycling_accidents_1915_osgb.osgb_east AS osgb_easting,
    cycling_accidents_1915_osgb.osgb_north AS osgb_northing,
    cycling_accidents_1915_osgb.longt AS wgs_longitude,
    cycling_accidents_1915_osgb.lat AS wgs_latitude,
    d_severity.label AS accident_severity,
    cycling_accidents_1915_osgb.n_cas AS number_of_casualties,
    cycling_accidents_1915_osgb.n_vei AS number_of_veichles,
    veichles0512_edi.vei_ref AS veichle_reference,
    d_vei_type.label AS veichle_type,
    casualties0512_edi.vei_ref AS casualty_veichle_reference,
    d_cas_type.label AS casualty_type,
    d_severity.label AS casualty_severity,
    d_cas_class.label AS casualty_class,
    d_age_band.label AS casualty_age_band,
    d_sex.label AS casualty_sex,
    cycling_accidents_1915_osgb.dat AS date_of_accident,
    d_day_of_week.label AS week_day,
    cycling_accidents_1915_osgb.tim AS time_of_accident,
    d_fst_road_class.label AS first_road_class,
    cycling_accidents_1915_osgb.fst_road_number AS first_road_num,
    d_scn_road_class.label AS second_road_class,
    cycling_accidents_1915_osgb.scn_road_num AS second_road_number,
    d_vei_loc.label AS veichle_location,
    d_junct_loc.label AS junction_location,
    d_manovra.label AS manovra,
    d_junct_det.label AS junction_detail,
    d_fst_impact_pt.label AS first_impact_pt,
    d_vei_leave_carr.label AS veichle_leav_carr,
    d_weather.label AS weather,
    cycling_accidents_1915_osgb.the_geom
   FROM cycling_accidents_1915_osgb,
    veichles0512_edi,
    casualties0512_edi,
    d_severity,
    d_vei_type,
    d_cas_type,
    d_junct_det,
    d_day_of_week,
    d_manovra,
    d_fst_road_class,
    d_scn_road_class,
    d_vei_loc,
    d_junct_loc,
    d_fst_impact_pt,
    d_vei_leave_carr,
    d_weather,
    d_age_band,
    d_cas_class,
    d_sex
  WHERE cycling_accidents_1915_osgb.acc_id::text =
veichles0512_edi.acc_id::text AND
cycling_accidents_1915_osgb.acc_id::text =
casualties0512_edi.acc_id::text AND
```

```
cycling_accidents_1915_osgb.acc_severity = d_severity.code AND
veichles0512_edi.vei_type = d_vei_type.code AND
cycling_accidents_1915_osgb.week_day = d_day_of_week.code AND
cycling_accidents_1915_osgb.junct_det = d_junct_det.code AND
veichles0512_edi.manovra = d_manovra.code AND
cycling_accidents_1915_osgb.fst_road_class = d_fst_road_class.code AND
cycling_accidents_1915_osgb.scn_road_class = d_scn_road_class.code AND
veichles0512_edi.vei_loc = d_vei_loc.code AND veichles0512_edi.junct_loc
= d_junct_loc.code AND veichles0512_edi.fst_impact_pt =
d_fst_impact_pt.code AND veichles0512_edi.vei_leave_carr =
d_vei_leave_carr.code AND cycling_accidents_1915_osgb.weather =
d_weather.code AND casualties0512_edi.cas_type = d_cas_type.code AND
casualties0512_edi.cas_age_band = d_age_band.code AND
casualties0512_edi.cas_class = d_cas_class.code AND
casualties0512_edi.cas_sex = d_sex.code AND
casualties0512_edi.cas_severity = d_severity.code
  ORDER BY cycling_accidents_1915_osgb.acc_id, veichles0512_edi.vei_ref;

ALTER TABLE acc_vei_cas
  OWNER TO postgres;
```

Appendix
IV

OSM2PO configuration file
and road network sql loader file

```
########################################################################
#
# CONVERTER
#
########################################################################

# Known Parsers detected by file extension.
# Other files or streams will be delegated to OsmXmlParser.

osmParser.pbf = de.cm.osm2po.plugins.OsmPbfParser
osmParser.o5m = de.cm.osm2po.plugins.OsmO5mParser
osmParser.o5m.gz = de.cm.osm2po.plugins.OsmO5mGzParser
osmParser.osm.bz2 = de.cm.osm2po.plugins.OsmXmlBz2Parser

# tileSize is the most important parameter for the conversion
# part. It controls the balance between available memory and
# the data size. The rule is simple: The more memory and the
# larger a tile the better. Examples:
# tileSize = 5x5 (Run with tileSize 5x5)
# tileSize = x, c (Run without tiling and run compression before)
# tileSize = 10x10, 0.5, c (Compress 10x10 with a buffer of 0.5)
# For most countries I recommend tileSize=x,c with -Xmx1408m.

#tileSize = 1x1,0.1

# A too small tileSize (size and/or buffer) ignores ways which have
# been tagged as one long section. In order to catch these,
# either increase the tileSize values or use the following option.
# Tipp: Read the Log while and/or after conversion,
# osm2po will report a warn message in such a case.

#fixTileSize = true

# osm2po's Joiner/TileManager must be able to cache lots of
# tiles (nodes). Therefore it has to estimate the remaining ram.
# If osm2po runs into OutOfMemoryErrors here, which mostly happens
# under 64 Bit Java, increase osm2po's own reservedXmx parameter (in Mb).

#reservedXmx = 512

# Skip regions with too few nodes (faster). Default is 0.

tileThreshold = 100

# Usually caching as many tiles as possible is the fastest approach.
# In some cases, mostly if these tiles contain hardly any nodes,
# this optimization may cause the opposite effect.

maxTilesPerLoop = 100

# Very useful Postprocess that renumbers vertexIDs by their location.

#useQuadTileOrder = true

# In order to modify ways programmatically this is your hook into the
Java-API.
```

```
#joinInterceptor = de.cm.osm2po.converter.DefaultJoinInterceptor

######################################################################
#
# DEFAULT TAG RESOLVER
#
######################################################################

# A TagResolver translates OSM-tags into a more useful set of information
# like name, speed, usage, ..., etc. If you need a special behavior,
# which cannot be handled by this default mechanism, feel free to
implement
# your own TagResolver. The default WayTagResolver utilizes two 32bit-
fields
# Each parsed osm-tag can modify flags in one of these fields
# either by allowing/setting bits (or-op.)
# or by denying/resetting bits (deferred inverse-and-op.).
# The default implementation is
'de.cm.osm2po.converter.DefaultWayTagResolver'
# Node- and RelationTagResolvers can only be influenced programmatically.

#wayTagResolver.class = com.to.another.package.YourWayTagResolver
#nodeTagResolver.class = com.to.another.package.YourNodeTagResolver
#relationTagResolver.class =
com.to.another.package.YourRelationTagResolver

# Using a prefix allows us to hold different configurations in one file

#wayTagResolver.prefix = wtr

# Custom flags with ascending binary values 1, 2, 4, 8 ...
# You can define up to 32 Flags (Bits).

wtr.flagList = car, bike, foot, rail, ferry

# only convert ways containing one of these flags

#wtr.finalMask = car
wtr.finalMask = car|bike
#wtr.finalMask = bike|foot
#wtr.finalMask = bike|car|foot

# very special hint for level_crossing modification

#wtr.shuttleTrainMask = rail|car

# Main-Tag definitions. Params 1-4:
# 1) concurrent order
# 2) class (1-127)
# 3) default speed in kmh
# 4) allowed transportation type (optional) - since v4.5.30

#wtr.tag.highway.motorway =       1, 11, 120, car
#wtr.tag.highway.motorway_link =  1, 12, 30,  car
wtr.tag.highway.trunk =          1, 13, 90,  car|bike
```

```
wtr.tag.highway.trunk_link =     1, 14, 30,  car|bike
wtr.tag.highway.primary =        1, 15, 70,  car|bike
wtr.tag.highway.primary_link =   1, 16, 30,  car|bike
wtr.tag.highway.secondary =      1, 21, 60,  car|bike
wtr.tag.highway.secondary_link = 1, 22, 30,  car|bike
wtr.tag.highway.tertiary =       1, 31, 40,  car|bike
wtr.tag.highway.residential =    1, 32, 50,  car|bike
wtr.tag.highway.road =           1, 41, 30,  car|bike
wtr.tag.highway.unclassified =   1, 42, 30,  car|bike
wtr.tag.highway.service =        1, 51, 5,   car|bike
wtr.tag.highway.living_street =  1, 63, 7,   car|bike|foot
wtr.tag.highway.pedestrian =     1, 62, 5,   bike|foot
wtr.tag.highway.track =          1, 71, 10,  bike|foot
wtr.tag.highway.path =           1, 72, 10,  bike|foot
wtr.tag.highway.cycleway =       1, 81, 15,  bike
wtr.tag.highway.footway =        1, 91, 5,   foot
wtr.tag.highway.steps =          1, 92, 5,   foot
wtr.tag.route.ferry =            2,  1, 10,  ferry
wtr.tag.route.shuttle_train =    2,  2, 50,  rail|car
wtr.tag.railway.rail =           3,  3, 50,  rail

# Other tags may overwrite the transportion type definition above.
# They allow or explicitly deny things, so the finalMask can
# catch or drop a set of tags at the end.
# Tags without explicit values like wtr.deny.motorcar act like
# an else-part and will be used if no other tag=value matches.
# Since Version 4.5.30 you may substitute keys. e.g.
# 'wtr.deny.motor[_vehicle|car]' will be replaced by
# 'wtr.deny.motor_vehicle' and 'wtr.deny.motorcar'.
# Nested expressions like ..[...[...]].. are not supported.

wtr.allow.motor[car|_vehicle].[yes|destination] = car
wtr.allow.[bicycle|cycleway] = bike

#tracktype is a classification of how well-maintained is a track or a
minor road
wtr.deny.tracktype.grade[4|5] = car|bike
#do not include those roads which do not provide access to the following
#transport means
#wtr.deny.access.no = bike|foot|rail|ferry
#wtr.deny.access.no = car|bike|foot|rail|ferry
#wtr.deny.vehicle.no = bike
#wtr.deny.vehicle.no = car|bike
#wtr.deny.motor[_vehicle|car] = car
wtr.deny.bicycle.no = bike
#wtr.deny.foot.no = foot

# Very important:
# If an OSM-maxSpeed-tag/value exists, it overrides the default
# speeds above. Disable this behavior if not needed, e.g. for bike
routing.

#wtr.maxSpeedOverrides = false
```

```
######################################################################
#
# LOGGER
#
######################################################################

# This is the LogLevel for global (log.level) and console
(log.console.level)
# and file logging. Possible values are
# debug, progress, warn, info (default), error and fatal.

log.level = debug
log.file.level = debug
log.console.level = progress
#log.console.writer.class = de.cm.osm2po.logging.Log2poConsoleWriter
#log.console.writer.class = de.cm.osm2po.logging.LogJclWriter

# Redirecting of StandardOut (console).
# Possible values are out (default), err or null (quiet).

#log.console.to = err

######################################################################
#
# POSTPROCESSORS
#
######################################################################

postp.0.class = de.cm.osm2po.converter.PgRoutingWriter

#postp.0.writeMultiLineStrings = true
postp.1.class = de.cm.osm2po.plugins.PgVertexWriter
#postp.2.class = de.cm.osm2po.converter.MlgBuilder
#postp.2.maxLevel = 3,10
#postp.3.class = de.cm.osm2po.sd.SdGraphBuilder

# postprocessors usually create output files.
# Use this parameter in order to print to stdout (console)

#postp.pipeOut = true

# Tip 1:
# If you want this program to be one link in a transformation chain
# e.g. curl | bzcat | osm2po | psql
# you must set both, log.console.to=err and postp.pipeOut=true.
# It is recommended to run curl, bzcat and psql in silent/quiet mode.
# Example (one line):
# curl -s -L http://download.geofabrik.de/europe/germany/hamburg-
latest.osm.bz2 |
# bzcat -c | java -jar osm2po-core-4.jar prefix=hh postp.pipeOut=true
log.console.to=err |
# psql -q -U myuser -s -d mydb
```

```
# Tip 2:
# If you enable the SdGraphBuilder for Android-Routing it is highly
# recommended to convert with useQuadTileOrder=true before.
# Another performance improvement can be reached by activating the
MlgBuilder




######################################################################
#
# OSM2PO-Routing
#
######################################################################

# This pluggable class translates other properties like kmh or flags
# and allows to mix in external data programmatically.

#graph.build.interceptor.class =
de.cm.osm2po.converter.DefaultGraphBuildInterceptor

# osm2po doubles segments to handle forward and reverse directions.
# Reverse edges which are derived from one-way-segments are
# written by default. This is useful for bike routing but
# not for car routing and blows up your graph size in memory.
# To exclude these "WrongWays" set the following parameter to true

#graph.build.excludeWrongWays = true

# Runtime parameters for the osm2po-Graph:
# In order to speed up geometry lookups you may want to set
# graph.support.segments=true. This disables HardDisk-Lookups but needs
# much more RAM (Xmx). Setting graph.support.edgeflags=true is useful
# for Soap/GeoJson-Requests. If not set, you will not receive street type
infos.
# Setting graph.support.reverse=true creates an additional Reverse-Graph.
# graph.support.raster[.e|.v] is another RAM-consuming addition, which
creates
# a rastered index for vertices (v) or edges (e) or if '.e' and '.v'
# are missing, for both.

#graph.support.segments = true
#graph.support.edgeflags = true
#graph.support.reverse = true
#graph.support.raster = true
#graph.support.raster.e = true
#graph.support.raster.v = true
#graph.support.barriers = true
#graph.support.extensions = true

# Here are osm2po's router implementations. They base on modified
# Dijkstra/AStar algorithms. Ovl-Routers are able to start and finish
# at any point, not only at links. Mlg-Routers need preprocessed data by
the
# MlgBuilder (see above), otherwise they will fall back to default
behavior.
```

```
# The MlgBuilder defines IDs for different use cases, as there are:
# ID  0  : Default Car-Routing with TurnRestrictions.
# ID +1  : For Shortest Path (not recommended)
# ID +2  : Ignore OneWay-Restrictions
# ID +4  : Ignore Turn-Restrictions
# To enable extensions set graph.support.extensions = true (see above)

#router.0.class=de.cm.osm2po.routing.DefaultRouter
#router.1.class=de.cm.osm2po.routing.EdgeRouter
#router.2.class=de.cm.osm2po.routing.PoiRouter
#router.3.class=de.cm.osm2po.routing.OvlRouter
#router.4.class=de.cm.osm2po.routing.OvlEdgeRouter
#router.5.class=de.cm.osm2po.routing.MlgRouter
#router.6.class=de.cm.osm2po.routing.MlgRevRouter
#router.7.class=de.cm.osm2po.routing.MlgBidiRouter
#router.8.class=de.cm.osm2po.routing.MlgOvlEdgeRouter


######################################################################
#
# OSM2PO-TinyWebServer (REST/SOAP)
#
######################################################################

#service.domain = localhost
#service.port = 8888


######################################################################
#
# OSM2PO-Samples (see Plugins Sources)
#
######################################################################

# TrafficSignals-Sample

#nodeClazz.1.name=Traffic Signals
#nodeTagResolver.class=de.cm.osm2po.samples.TrafficSignalsNodeTagResolver
#router.1.class=de.cm.osm2po.samples.TrafficSignalsRouter
```

Road network sql loader file:

```
-- Created by  : osm2po-core
-- Version     : 4.8.8
-- Author (c)  : Carsten Moeller - info@osm2po.de
-- Date        : Sat Jun 21 13:13:33 BST 2014

DROP TABLE IF EXISTS edinburgh_4_2po_4pgr;
-- SELECT DropGeometryTable('edinburgh_4_2po_4pgr');

CREATE TABLE edinburgh_4_2po_4pgr(id integer, osm_id bigint, osm_name
character varying, osm_meta character varying, osm_source_id bigint,
```

```
osm_target_id bigint, clazz integer, flags integer, source integer,
target integer, km double precision, kmh integer, cost double precision,
reverse_cost double precision, x1 double precision, y1 double precision,
x2 double precision, y2 double precision);
SELECT AddGeometryColumn('edinburgh_4_2po_4pgr', 'geom_way', 4326,
'LINESTRING', 2);

INSERT INTO edinburgh_4_2po_4pgr VALUES
(1, 137, 'Great King Street', null, 609491, 609526, 32, 3, 107, 108,
0.20566073, 48, 0.0042845984, 0.0042845984, -3.19957, 55.95781, -3.19641,
55.95835,
'0102000020E610000002000000D1AFA27B89809C011E4A08499FA4B40E0DBF4673F9209
C0910F7A36ABFA4B40'),
(2, 3466, 'Great King Street', null, 609523, 609491, 32, 3, 109, 107,
0.21015562, 48, 0.004378242, 0.004378242, -3.2028, 55.95726, -3.19957,
55.95781,
'0102000020E610000002000000C8073D9B559F09C06DE2E47E87FA4B400D1AFA27B89809
C011E4A08499FA4B40'),
(3, 3468, 'Albyn Place', null, 606310, 320845744, 31, 3, 110, 111,
0.049217522, 48, 0.0010253651, 0.0010253651, -3.20748, 55.95334, -3.20673,
55.95348,
'0102000020E610000002000000B7973446EBA809C0FCFB8C0B07FA4B400FD1E80E62A709
C0EEB1F4A10BFA4B40'),


--all rows were not reported for a matter of space


(69809, 280736759, null, null, 448896187, 2847976984, 51, 3, 105, 57130,
0.26993003, 5, 0.053986005, 0.053986005, -2.77356, 56.00183, -2.77235,
55.9995,
'0102000020E61000000500000038F3AB39403006C06A1327F73B004C401DACFF73982F06
C0AA60545227004C4091442FA3582E06C08E588B4F01004C40598638D6C52D06C079AF5A9
9F0FF4B40598638D6C52D06C00E2DB29DEFFF4B40'),
(69810, 280736759, null, null, 2847976984, 2847976992, 51, 3, 57130, 106,
0.24647014, 5, 0.04929403, 0.04929403, -2.77235, 55.9995, -2.77618,
55.99918,
'0102000020E610000009000000598638D6C52D06C00E2DB29DEFFF4B403D0FEECEDA2D06
C080D4264EEEFF4B4059FAD005F52D06C015527E52EDFF4B403CF71E2E392E06C0F27B9BF
EECFF4B40DE718A8EE43206C007EBFF1CE6FF4B404F92AE997C3306C04E97C5C4E6FF4B40
F8889812493406C000C63368E8FF4B4030478FDFDB3406C0726DA818E7FF4B4068791EDC9
D3506C09D685721E5FF4B40');

ALTER TABLE edinburgh_4_2po_4pgr ADD CONSTRAINT pkey_edinburgh_4_2po_4pgr
PRIMARY KEY(id);
CREATE INDEX idx_edinburgh_4_2po_4pgr_source ON
edinburgh_4_2po_4pgr(source);
CREATE INDEX idx_edinburgh_4_2po_4pgr_target ON
edinburgh_4_2po_4pgr(target);
```

Appendix
V
Suitability scores and cost attribution

Infrastructure suitability score attribution:

```
UPDATE "osm_cycling_wgs84_join_3"
SET sum_road_suit = (
CASE WHEN clazz=15 THEN  1
WHEN bi_cost=-1 THEN -1
WHEN clazz=16 THEN  1
WHEN clazz=21 THEN  2
WHEN clazz=22 THEN  3
WHEN clazz=31 THEN  4
WHEN clazz=41 THEN  5
WHEN clazz=42 THEN  6
WHEN clazz=32 THEN  7
WHEN clazz=51 THEN  7
WHEN clazz=63 THEN  8
WHEN clazz=62 THEN  9
WHEN clazz=71 THEN  9
WHEN clazz=72 THEN  10
WHEN clazz=81 THEN  10
WHEN clazz=91 THEN  10
WHEN clazz=92 THEN  -1
ELSE 10
END);
```

Query create to determine intersection severity outcomes, and results:

```
select count (*) as count, junction_detail, casualty_severity from
acc_vei_cas where
casualty_veichle_reference = veichle_reference
and veichle_type= 'Pedal cycle'
group by junction_detail, casualty_severity
order by junction_detail;
```

```
count junction_detail casualty_severity
1 "Crossroads" "Fatal"
37 "Crossroads" "Serious"
212 "Crossroads" "Slight"
4 "Mini-roundabout" "Serious"
37 "Mini-roundabout" "Slight"
9 "More than 4 arms (not roundabout)" "Serious"
61 "More than 4 arms (not roundabout)" "Slight"
4 "Not at junction or within 20 metres" "Fatal"
97 "Not at junction or within 20 metres" "Serious"
400 "Not at junction or within 20 metres" "Slight"
22 "Other junction" "Serious"
127 "Other junction" "Slight"
3 "Private drive or entrance" "Serious"
18 "Private drive or entrance" "Slight"
27 "Roundabout" "Serious"
155 "Roundabout" "Slight"
```

```
6 "Slip road" "Serious"
11 "Slip road" "Slight"
4 "T or staggered junction" "Fatal"
98 "T or staggered junction" "Serious"
571 "T or staggered junction" "Slight"
```

Type of intersection score attribution:

```
UPDATE “acc_vei_cas”
SET junct_suit =  (
CASE WHEN junction_d = 'T or staggered junction'THEN 1
WHEN junction_d = 'Not at junction or within 20 metres'THEN 2
WHEN junction_d = 'Crossroads'THEN 3
WHEN junction_d = 'Roundabout'THEN 4
WHEN junction_d = 'Other junction'THEN 5
WHEN junction_d = 'More than 4 arms (not roundabout)'THEN 6
WHEN junction_d = 'Private drive or entrance'THEN 8
WHEN junction_d = 'Mini-roundabout'THEN 7
WHEN junction_d = 'Slip road'THEN 9
ELSE 10
END);
```

Crash frequency score attribution:

```
UPDATE “osm_cycling_wgs84_join_3”
SET acc_sui = (
CASE WHEN acc_count = 0 THEN 10
WHEN acc_count = 9 THEN  0.90
WHEN acc_count = 8 THEN  2.70
WHEN acc_count = 7 THEN  3.60
WHEN acc_count = 6 THEN  4.50
WHEN acc_count = 5 THEN  5.40
WHEN acc_count = 4 THEN  6.30
WHEN acc_count = 3 THEN  7.20
WHEN acc_count = 2 THEN  8.10
WHEN acc_count = 1 THEN  9.00
ELSE 10
END);
```

Query create to determine manoeuvres severity outcomes, and results:

```
select manovra, casualty_severity, count (*) as count,casualty_type from
acc_vei_cas where
casualty_veichle_reference = veichle_reference
and veichle_type = 'Pedal cycle'
and casualty_type = 'Cyclist'
group by casualty_severity, manovra, casualty_type
order by count desc, casualty_SEVERITY;
```

```
 manovra severity count cas_type

"Going ahead other" "Slight" 1272 "Cyclist"
"Going ahead other" "Serious" 239 "Cyclist"
"Turning right" "Slight" 51 "Cyclist"
"Overtaking static vehicle - offside" "Slight" 38 "Cyclist"
"Moving off" "Slight" 34 "Cyclist"
"Turning left" "Slight" 29 "Cyclist"
"Slowing or stopping" "Slight" 23 "Cyclist"
"Waiting to go - held up" "Slight" 17 "Cyclist"
"Overtaking - nearside" "Slight" 16 "Cyclist"
"Going ahead right-hand bend" "Slight" 15 "Cyclist"
"Going ahead left-hand bend" "Slight" 15 "Cyclist"
"Overtaking moving vehicle - offside" "Slight" 13 "Cyclist"
"Reversing" "Slight" 10 "Cyclist"
"Going ahead other" "Fatal" 9 "Cyclist"
"Turning right" "Serious" 9 "Cyclist"
"Changing lane to right" "Slight" 7 "Cyclist"
"Overtaking static vehicle - offside" "Serious" 6 "Cyclist"
"Moving off" "Serious" 6 "Cyclist"
"Slowing or stopping" "Serious" 6 "Cyclist"
"Waiting to turn right" "Slight" 6 "Cyclist"
"Overtaking - nearside" "Serious" 5 "Cyclist"
"Turning left" "Serious" 4 "Cyclist"
"Going ahead right-hand bend" "Serious" 4 "Cyclist"
"Changing lane to right" "Serious" 3 "Cyclist"
"U-turn" "Slight" 3 "Cyclist"
"Waiting to turn right" "Serious" 2 "Cyclist"
"Waiting to go - held up" "Serious" 2 "Cyclist"
"Going ahead left-hand bend" "Serious" 2 "Cyclist"
"Reversing" "Serious" 2 "Cyclist"
"Overtaking moving vehicle - offside" "Serious" 2 "Cyclist"
"Waiting to turn left" "Slight" 2 "Cyclist"
"Parked" "Slight" 2 "Cyclist"
"Data missing or out of range" "Slight" 2 "Cyclist"
"U-turn" "Serious" 1 "Cyclist"
```

Manoeuvre type score attribution:

```
UPDATE "acc_vei_cas"
SET man_suit = (
CASE WHEN  manovra = 'Going ahead other' THEN  0.50
 WHEN  manovra = 'Turning right' THEN  1
 WHEN  manovra = 'Turning left' THEN  3
 WHEN  manovra = 'Moving off' THEN  2
 WHEN  manovra = 'Parked' THEN  8
 WHEN  manovra = 'Slowing or stopping' THEN  2.50
 WHEN  manovra = 'Waiting to go - held up' THEN  4.50
 WHEN  manovra = 'Overtaking moving vehicle - offside' THEN 6
 WHEN  manovra = 'U-turn' THEN  7.50
 WHEN  manovra = 'Reversing' THEN  6.50
 WHEN  manovra = 'Waiting to turn right' THEN  7
 WHEN  manovra = 'Going ahead right-hand bend' THEN  4
 WHEN  manovra = 'Going ahead left-hand bend' THEN  5.50
```

```
 WHEN  manovra = 'Overtaking static vehicle - offside' 6
 WHEN  manovra = 'Waiting to turn left' THEN  9
 WHEN  manovra = 'Overtaking - nearside' THEN  3.50
 WHEN  manovra = 'Changing lane to right' THEN  5
 WHEN  manovra = 'Data missing or out of range' THEN  8
ELSE man_suit 10

END)
WHERE veichle_ty = 'Pedal cycle' and
casualty_t = 'Cyclist'
```

Type of vehicles involved score attribution:

```
UPDATE "acc_vei_cas"
SET vei_suit = (
CASE WHEN  veichle_ty LIKE '%goods 7.5 tonnes%' THEN  3
 WHEN  veichle_ty LIKE 'Bus%' THEN 3
 WHEN  veichle_ty LIKE '%under 7.5 tonnes%' THEN 4
 WHEN  veichle_ty LIKE '%Minibus (8 - 16%' THEN 4
 WHEN  veichle_ty LIKE '%3.5 tonnes or under' 4.5
 WHEN  veichle_ty = 'Car' THEN  5
 WHEN  veichle_ty LIKE '%Taxi%' THEN  5
 WHEN  veichle_ty LIKE '%Other%' THEN  5
 WHEN  veichle_ty LIKE '%over 500cc%' THEN  5.5
 WHEN  veichle_ty LIKE '%125cc and up to 500cc%' THEN  6
 WHEN  veichle_ty LIKE '%125cc and under%' THEN  7
 WHEN  veichle_ty LIKE '%50cc and under%' THEN  8
 WHEN  veichle_ty LIKE '%Agricultural%' THEN  8
ELSE 10
END);
```

Query used to detect multiple vehicles collisions:

```
Select distinct id_accident from acc_vei_cas
where number_of_veichles > 2;
```

Query used to detect cycling collisions:

```
WITH dups as (
  SELECT *,
  ROW_NUMBER() OVER(PARTITION BY id_accident ORDER BY id_accident asc) AS
Row
  FROM acc_vei_cas
  WHERE veichle_ty = 'Pedal cycle'
  AND casualty_c = 'Driver or rider')
UPDATE acc_vei_cas SET c_type = 'Cyclist'
FROM dups
where
```

```
dups.Row > 1
AND dups.id_accident = acc_vei_cas.id_accident;
```

Casualty severity score attribution:

```
UPDATE "acc_vei_cas"
SET sev_suit = (
CASE WHEN  severity = 'Slight' THEN  7
 WHEN  severity = 'Serious' THEN  4
 WHEN  severity = 'Fatal' THEN  1
 ELSE 10
 END);
```

Costs attribution:

```
UPDATE osm_cycling_wgs84_join_3
--set the cost column and weighted costs
SET bi_cost = (km*0.25)/(suit_tot*0.75)
WHERE
--exclude cycle paths, tracks and one way streets
clazz != 13 AND
clazz!=14 AND
kmh_avg !=0 AND
km !=0 AND
bi_cost !=0 AND
bi_cost != -1;
```

Appendix VI

PgRouting queries

Example of a PgRouting query retrieving the shortest path given two nodes ID with Dijkstra's algorithm:

```
SELECT seq, id1 as node, id2 as edge, bi_cost, the_geom
FROM pgr_dijkstra('SELECT gid::int4 as id, source::int4 ,target::int4,
bi_cost::float8 as cost, reverse_bi_cost::float8 as reverse_cost FROM
osm_cycling_wgs84_join_3',
511,3735, false, true) AS di, osm_cycling_wgs84_join_3 AS t
Where t.gid= di.id2;
```

PL-Pgsql function used in our web-service to retrieve the shortest path with Dijkstra's algorithm given a set of x,y coordinates:

```
DECLARE
--declare function variables and data types
        sql     text;
        rec     record;
        source  integer;
        target  integer;
        point   integer;

BEGIN
        -- Find nearest node
        EXECUTE 'SELECT id::integer FROM vertices_tmp
                        ORDER BY the_geom <->
ST_GeometryFromText(''POINT('
                        || x1 || ' ' || y1 || ')'',4326) LIMIT 1' INTO
rec;
        source := rec.id;

        EXECUTE 'SELECT id::integer FROM vertices_tmp
                        ORDER BY the_geom <->
ST_GeometryFromText(''POINT('
                        || x2 || ' ' || y2 || ')'',4326) LIMIT 1' INTO
rec;
        target := rec.id;

        -- Shortest path query (TODO: limit extent by BBOX)
        seq := 0;
        sql := 'SELECT gid, the_geom, osm_name, bi_cost, source, target,
                                ST_Reverse(the_geom) AS flip_geom FROM '
||
                        'pgr_dijkstra(''SELECT gid as id, source::int,
target::int, '
                                        || 'bi_cost::float AS cost,'
                                        || 'reverse_bi_cost::float AS
reverse_cost FROM '
                                        || quote_ident(tbl) || ''', '
                                        || source || ', ' || target
                                        || ' , false, true), '
                                || quote_ident(tbl) || ' WHERE id2 = gid
ORDER BY seq';
```

```
        -- Remember start point
        point := source;

        FOR rec IN EXECUTE sql
        LOOP
                -- Flip geometry (if required)
                IF ( point != rec.source ) THEN
                        rec.the_geom := rec.flip_geom;
                        point := rec.source;
                ELSE
                        point := rec.target;
                END IF;

                -- Calculate heading (simplified)
                EXECUTE 'SELECT degrees( ST_Azimuth(
                                ST_StartPoint(''' || rec.the_geom::text
|| '''),
                                ST_EndPoint(''' || rec.the_geom::text ||
''') ) )'
                        INTO heading;

                -- Return record
                seq     := seq + 1;
                gid     := rec.gid;
                name    := rec.osm_name;
                cost    := rec.bi_cost;
                geom    := rec.the_geom;
                RETURN NEXT;
        END LOOP;
        RETURN;
END;
```

Appendix
VII

Web-GIS code

HTML page:

```
<!DOCTYPE HTML>
<html>
  <head>
    <title>OpenLayers Demo</title>
    <link rel="stylesheet" href="default/style.css" type="text/css">
    <style type="text/css">
    html, body, #basicMap {
          width: 100%;
          height: 99%;
          margin: 0;
                }

                #panel{
                position: relative;
                float: left;
                top: -15px;
                left: 0px;
                height: 3%;
                width: 80%;
                }


          #basicMap .olControlZoomBoxItemInactive{
              width: 22px;
              height: 22px;
              background: #999933
url('http://dev.openlayers.org/releases/OpenLayers-2.9.1/img/drag-
rectangle-off.png');
              }

          #basicMap .olControlZoomBoxItemActive{
              width: 22px;
              height: 22px;
              background: #999933
url('http://dev.openlayers.org/releases/OpenLayers-2.9.1/img/drag-
rectangle-off.png');
              }
          #sel{

          opacity: 1;
          float:right;
          position: relative;
          top: -38px;
          left: -320px;

          }


    </style>
    <script src="http://openlayers.org/api/OpenLayers.js"></script>
    <script src= "Open_layers_book_2.js"></script>
```

```
    <script src=
"http://maps.google.com/maps/api/js?sensor=false&v=3.2"></script>
  </head>
  <body onload="init();">
   <div id="panel">
   <p><b>Edinburgh's Cycling Accidents Heat Map, Years 2005-2012, Source:
Department for Transport UK</b></p>
      <div id='sel'>
     <select id='selection' onchange="change_heatmap()">
     <option selected="">Select collision type</option>
     <option value="Default">All Cycling Accidents</option>
     <option value="Cars">Cars</option>
     <option value="Taxi_Private_hire_car">Taxis</option>
     <option value="Vans_3_5_Tonnes">Vans Under 3.5 Tonnes</option>
     <option value="Buses_Minibuses">Buses</option>
     <option value="Over_3_5_Tonnes">Trucks Over 3.5 Tonnes</option>
     <option value="Motorcycles">Motorcycles</option>
     <option value="Cyclist">Cycles Collisions</option>
     <option value="Pedestrian">Pedestrians</option>
     <option value="Agricultural Vehicle">Agricultural Vehicle</option>
     </select>
     </div>

     </div>

  <div id="basicMap"></div>

  </body>
</html>
```

Java Script functions:

```
var heatmap
                      //                        + lonlat.lon + " E");
                //}




            //});

 function init() {





        var navigation_control = new OpenLayers.Control.Navigation({});
        var markers;
        var end;

        var controls_array = [
        navigation_control,
        new OpenLayers.Control.PanZoomBar({}),
        new OpenLayers.Control.LayerSwitcher({}),
```

```
        new OpenLayers.Control.Permalink(),
        new OpenLayers.Control.MousePosition({
            prefix: '<a target= "_blank" ' +
'href="http://spatialreference.org/ref/epsg/3857/">'+
            'EPSG:3857<a/> coordinates:',
            separator: ' -- ',
            numDigits: 4,
            emptyString:'null'}),
        new OpenLayers.Control.OverviewMap({
        size : new OpenLayers.Size(400,200)}),
        new OpenLayers.Control.KeyboardDefaults(),
        new OpenLayers.Control.Attribution({})
        ];



        zoom_box = new OpenLayers.Control.ZoomBox();

        nav = new OpenLayers.Control.NavigationHistory();
        control_panel = new OpenLayers.Control.Panel ({

        });

        control_panel.addControls ([nav.next, nav.previous,zoom_box]);

        map = new OpenLayers.Map("basicMap", {
        controls: controls_array});
        map.addControl(new OpenLayers.Control.ScaleLine({}));
        map.addControl(nav);
        map.addControl(control_panel);
        control_panel.moveTo(new OpenLayers.Pixel(18,290));




        var OSM_attributions = {
        title: "Provided by OpenStreetMap",
        href: "http://www.openstreetmap.org"
        }
        var cyclemap  = new OpenLayers.Layer.OSM("OpenCycleMap",
        ["http://a.tile.opencyclemap.org/cycle/${z}/${x}/${y}.png",
          "http://a.tile.opencyclemap.org/cycle/${z}/${x}/${y}.png",
          "http://a.tile.opencyclemap.org/cycle/${z}/${x}/${y}.png"],
          OSM_attributions);
        var fromProjection = new OpenLayers.Projection("EPSG:4326");   //
Transform from WGS 1984
        var toProjection   = new OpenLayers.Projection("EPSG:900913"); //
to Spherical Mercator Projection
        var position       = new OpenLayers.LonLat(-3.1933,
55.9503).transform(fromProjection, toProjection);
        var zoom           = 12;
        var OSM_network = new OpenLayers.Layer.WMS("OSM Roads Network",
"http://localhost:8080/geoserver/wms",
        {layers: 'pg_routing:osm_cycling_wgs84_join_3',
        transparent: "true",
        format : "image/png"},
```

```
        {projection: 'EPSG:900913'});

        OSM_network.setVisibility(false);




         heatmap = new OpenLayers.Layer.WMS("Accidents 2005-2012 DfT -
Heatmap","http://localhost:8080/geoserver/wms",
        {layers:'cite:heatmap,cite:heatmap',
        transparent: "true",
        styles: "point,heatmap",
        format : "image/png",
        },
        {projection: 'EPSG:900913',
        opacity: 1,
        singleTile: true});
        heatmap.setVisibility(false);

        var accidents = new OpenLayers.Layer.WMS("Accidents 2005-2012
DfT","http://localhost:8080/geoserver/wms",
        {layers:'pg_routing:acc_count_severity',
        transparent: "true",
        format : "image/png"},
        {projection: 'EPSG:900913',
        opacity: 1});
        accidents.setVisibility(false);




        markers = new OpenLayers.Layer.Markers("Markers");
        markers.id = "Markers";

        var google_sat = new OpenLayers.Layer.Google("Google Hybrid",
        {type: google.maps.MapTypeId.HYBRID, numZoomLevels:19});




map.addLayers([cyclemap,google_sat,OSM_network,accidents,heatmap,markers]
);
        map.setCenter(position, zoom );
        google_sat.mapObject.setTilt(0);

        map.events.register('click',map, add_start);


          var i = 0;
          var start_point;
          var start_coords;
          var end_coords;
          var x2;
```

```
          var end_point;
          var params = {
                      LAYERS: 'pg_routing:pg_routing',
                      FORMAT: 'image/png'
                        };



            function add_start (e){

                        if (start_coords == undefined){
                        start_coords = map.getLonLatFromPixel(e.xy);
                        var size = new OpenLayers.Size(21,25);
                        var offset = new OpenLayers.Pixel (-(size.w/2), -
size.h);
                        var start_point = new
OpenLayers.Icon('http://www.openlayers.org/dev/img/marker-
green.png',size,offset);
                        var markerslayer = map.getLayer('Markers');
                        markerslayer.addMarker(new
OpenLayers.Marker(start_coords,start_point));

                        alert("Start cordinates at " + start_coords.lat +
" N, " +
                                                      + start_coords.lon + " E");
                                                      }
                                                      else

                                                      add_end(e);
                                                         }






           function add_end (e) {

           end_coords = map.getLonLatFromPixel(e.xy);
                        var size = new OpenLayers.Size(21,25);
                        var offset = new OpenLayers.Pixel (-(size.w/2), -
size.h);
                        var end_point = new
OpenLayers.Icon('http://www.openlayers.org/dev/img/marker.png',size,offse
t);
                        var markerslayer = map.getLayer('Markers');
                        markerslayer.addMarker(new
OpenLayers.Marker(end_coords,end_point));
                        alert("End cordinates at " + start_coords.lat + "
N, " +
                                                           + start_coords.lon + "
E");
                        var x1 = start_coords.transform(toProjection,
fromProjection).lon;
```

```
                        var x2 = start_coords.transform("900913",
"4326").lat;
                        var y1 = end_coords.transform(toProjection,
fromProjection).lon;
                        var y2 = end_coords.transform("900913",
"4326").lat;
                        var viewparams = [
                                    'x1:'+x1+';x2:'+x2+
                                    ';y1:'+y1+';y2:'+ y2
                                    ];

                       start_coords = undefined;



                        var safe_path = new OpenLayers.Layer.WMS("Safe
Path","http://localhost:8080/geoserver/wms",
                               {layers : "pg_routing:pg_routing",
                                format : "image/png8",
                                transparent : true,
                                viewparams: viewparams,
                                styles : "simple_roads"},
                                {projection: 'EPSG:900913'});


                        var quiet_path = new OpenLayers.Layer.WMS("Quiet
Path","http://localhost:8080/geoserver/wms",
                               { layers : "pg_routing:pg_routing_ncost",
                                format : "image/png8",
                                transparent : true,
                                viewparams: viewparams

                                },
                                {projection: 'EPSG:900913',
                                opacity : 0.6 });



map.addLayers([heatmap,quiet_path,safe_path]);
                                map.setLayerIndex(accidents,2);
                                map.setLayerIndex(quiet_path,0);
                                map.setLayerIndex(safe_path,1)
                                accidents.setOpacity(0.6);

                                start_coords = undefined}

           }
           function change_heatmap(){
           var e = OpenLayers.Util.getElement('selection').value;
           heatmap.mergeNewParams({viewparams: "word:"+e});
           }
```

Appendix VIII

Algorithms empirical test results

ATEMPT	ALGORITHM	ID START	ID END	LENGTH m	SUITABILITY SCORE DIFFERENCE	LENGTH DIFFERENCE metres	LENGTH % DIFFERENCE	TOTAL SUITABILITY	SUITABILITY SCORE	SUITABILITY SCORE DIFFERENCE	% SUITABILITY SCORE DIFFERENCE
	DIJKSTRA WITH ACCIDENTS	986	6108	2530.36	0.013858127	277.8	9.892598712	1950	0.770641332		
1	DIJKSTRA WITHOUT ACCIDENTS	986	6108	2808.16				2203	0.784499459	0.013858127	1.766492876
	DIJKSTRA WITH ACCIDENTS	494	6538	2793.6	0.116687661	5.49	0.196520619	2738	0.980097365		
2	DIJKSTRA WITHOUT ACCIDENTS	494	6538	2799.09				3070	1.096785027	0.116687661	10.63906402
	DIJKSTRA WITH ACCIDENTS	166	3445	3527.01	0.288425316	1005.69	22.18743795	3873	1.098097255		
3	DIJKSTRA WITHOUT ACCIDENTS	166	3445	4532.7				3670	0.809671939	0.288425316	26.26591719
	DIJKSTRA WITH ACCIDENTS	8713	1700	4808.39	0.120716643	1735.69	26.52305595	3521	0.732261734		
4	DIJKSTRA WITHOUT ACCIDENTS	8713	1700	6544.08				4002	0.611545091	0.120716643	16.48545013
	DIJKSTRA WITH ACCIDENTS	16153	22712	2977.42	0.003177156	1537.51	34.0539056	2511	0.843347596		
5	DIJKSTRA WITHOUT ACCIDENTS	16153	22712	4514.93				3822	0.846524752	0.003177156	0.375317564
	DIJKSTRA WITH ACCIDENTS	11398	2729	2260.88	0.30016274	-71.29	-3.153196985	2054	0.908495807		
6	DIJKSTRA WITHOUT ACCIDENTS	11398	2729	2189.59				1332	0.608333067	0.30016274	33.03952949
	DIJKSTRA WITH ACCIDENTS	874	3714	1524.25	0.209969226	938.42	38.10579574	1704	1.117926849		
7	DIJKSTRA WITHOUT ACCIDENTS	874	3714	2462.67				2236	0.907957623	0.209969226	18.78201836
	DIJKSTRA WITH ACCIDENTS	9173	781	3452.19	0.012030698	461.98	11.80275767	3184	0.922313082		
8	DIJKSTRA WITHOUT ACCIDENTS	9173	781	3914.17				3563	0.910282384	0.012030698	1.304405021
	DIJKSTRA WITH ACCIDENTS	5523	4282	2398.1	0.158719519	410.54	14.61703885	1888	0.787289938		
9	DIJKSTRA WITHOUT ACCIDENTS	5523	4282	2808.64				2657	0.946009457	0.158719519	16.77779409
	DIJKSTRA WITH ACCIDENTS	589	481	1621.9	0	0	0	1548	0.954436155		
10	DIJKSTRA WITHOUT ACCIDENTS	589	481	1621.9				1548	0.954436155	0	0
	DIJKSTRA WITH ACCIDENTS	10960	11251	10948.68	0.024442935	61.69	0.560289981	6944	0.634231706		
11	DIJKSTRA WITHOUT ACCIDENTS	10960	11251	11010.37				6714	0.609788772	0.024442935	3.853943971
	DIJKSTRA WITH ACCIDENTS	9121	108	3225.98	0.060554784	24.04	0.739687756	2255	0.699012393		
12	DIJKSTRA WITHOUT ACCIDENTS	9121	108	3250.02				2075	0.638457609	0.060554784	8.662905585
	DIJKSTRA WITH ACCIDENTS	8059	334	5314.07	0.196699461	1238.14	18.89652499	4553	0.85678209		
13	DIJKSTRA WITHOUT ACCIDENTS	8059	334	6552.21				4325	0.660082629	0.196699461	22.95793336
	DIJKSTRA WITH ACCIDENTS	522	1366	3927.69	0.194777329	1522.6	60.17325598	3370	0.858010688		
14	DIJKSTRA WITHOUT ACCIDENTS	522	1366	5450.29				5738	1.052788017	0.194777329	18.50109666
	DIJKSTRA WITH ACCIDENTS	41153	23785	3008.74	0.028188936	41.682	1.36643389	2816	0.935939962		
15	DIJKSTRA WITHOUT ACCIDENTS	41153	23785	3050.422				2941	0.964128898	0.028188936	2.923772544
	DIJKSTRA WITH ACCIDENTS	4888	711	5296.96	0.059584134	513.67	8.840177399	5659	1.068348638		
16	DIJKSTRA WITHOUT ACCIDENTS	4888	711	5810.63				6554	1.127932771	0.059584134	5.282596205
	DIJKSTRA WITH ACCIDENTS	18821	32634	5996.02	0.18534659	1094.67	15.43813084	5298	0.883586112		
17	DIJKSTRA WITHOUT ACCIDENTS	18821	32634	7090.69				4951	0.698239523	0.18534659	20.97663001
	DIJKSTRA WITH ACCIDENTS	15155	585	5633.35	0.061084914	1098.43	16.31708107	4630	0.821891059		
18	DIJKSTRA WITHOUT ACCIDENTS	15155	585	6731.78				5944	0.882975974	0.061084914	6.918072065
	DIJKSTRA WITH ACCIDENTS	36918	895	4772.68	0.064320886	388.66	7.530215022	4310	0.903056564		
19	DIJKSTRA WITHOUT ACCIDENTS	36918	895	5161.34				4329	0.838735677	0.064320886	7.122575598
	DIJKSTRA WITH ACCIDENTS	5664	576	3968.03	0.184897922	1605.9	28.81091079	3399	0.856596346		
20	DIJKSTRA WITHOUT ACCIDENTS	5664	576	5573.93				3744	0.671698425	0.184897922	21.58518682

First test results When the column "ATTEMPT" is marked in red, this means overal better performance in terms of suitability of the accidents non-optimised algorithm, viceversa in green.

ATEMPT	ALGORITHM	ID START	ID END	LENGTH m	SUITABILITY SCORE DIFFERENCE	LENGTH DIFFERENCE metres	LENGTH % DIFFERENCE	TOTAL SUITABILITY	SUITABILITY SCORE	SUITABILITY SCORE DIFFERENCE	% SUITABILITY SCORE DIFFERENCE
	DIJKSTRA WITH ACCIDENTS	970	1951	1843.56	0.039072557	1208.96	39.60530971	2014	1.092451561		
21	**DIJKSTRA WITHOUT ACCIDENTS**	970	1951	3052.52				3454	1.131524118	0.039072557	3.453090929
	DIJKSTRA WITH ACCIDENTS	1108	5724	2889.84	0.083952465	521.55	15.28848944	1875	0.648824848		
22	**DIJKSTRA WITHOUT ACCIDENTS**	1108	5724	3411.39				1927	0.564872383	0.083952465	12.93915688
	DIJKSTRA WITH ACCIDENTS	15782	5023	2564.46	0.09579563	426.32	14.25447542	1952	0.761173892		
23	**DIJKSTRA WITHOUT ACCIDENTS**	15782	5023	2990.78				1990	0.665378263	0.09579563	12.58524902
	DIJKSTRA WITH ACCIDENTS	5132	3586	8724.27	0.029856329	396.92	4.351625172	8587	0.984265732		
24	**DIJKSTRA WITHOUT ACCIDENTS**	5132	3586	9121.19				9250	1.014122061	0.029856329	2.944056709
	DIJKSTRA WITH ACCIDENTS	4370	4238	1429.16	0.191411101	129.89	8.331355633	1490	1.042570461		
25	**DIJKSTRA WITHOUT ACCIDENTS**	4370	4238	1559.05				1327	0.85115936	0.191411101	18.35953619
	DIJKSTRA WITH ACCIDENTS	5260	5749	1750	0	0	0	1276	0.729142857		
26	**DIJKSTRA WITHOUT ACCIDENTS**	5260	5749	1750				1276	0.729142857	0	0
	DIJKSTRA WITH ACCIDENTS	614	700	1656.11	0.153261836	781.8	32.06845208	1276	0.770480222		
27	**DIJKSTRA WITHOUT ACCIDENTS**	614	700	2437.91				2252	0.923742058	0.153261836	16.59141042
	DIJKSTRA WITH ACCIDENTS	8526	3421	3235.28	0.007813888	-15.62	-4.828021068	2867	0.886167503		
28	**DIJKSTRA WITHOUT ACCIDENTS**	8526	3421	3219.66				2828	0.878353615	0.007813888	0.881762
	DIJKSTRA WITH ACCIDENTS	304	8769	1807.83	0	0	0	1826	1.010050724		
29	**DIJKSTRA WITHOUT ACCIDENTS**	304	8769	1807.83				1826	1.010050724	0	0
	DIJKSTRA WITH ACCIDENTS	10502	445	2554.4	0.022214149	763.6	23.01386377	1966	0.769652365		
30	**DIJKSTRA WITHOUT ACCIDENTS**	10502	445	3318				2480	0.747438216	0.022214149	2.886257456
	DIJKSTRA WITH ACCIDENTS	1037	42937	1605.54	0.032320057	518.38	24.40675732	1340	0.834610162		
31	**DIJKSTRA WITHOUT ACCIDENTS**	1037	42934	2123.92				1704	0.802290105	0.032320057	3.872473483
	DIJKSTRA WITH ACCIDENTS	786	217	1668.87	0.089316241	62.74	3.623217699	2403	1.439896457		
32	**DIJKSTRA WITHOUT ACCIDENTS**	786	217	1731.61				2648	1.529212698	0.089316241	5.840668289
	DIJKSTRA WITH ACCIDENTS	17249	165	1996.62	0.203011317	-84.21	-4.217627791	2389	1.196522122		
33	**DIJKSTRA WITHOUT ACCIDENTS**	17249	165	1912.41				1900	0.993510806	0.203011317	16.96678338
	DIJKSTRA WITH ACCIDENTS	18442	408	1597.67	0	0	0	1435	0.898182979		
34	**DIJKSTRA WITHOUT ACCIDENTS**	18442	408	1597.67				1435	0.898182979	0	0
	DIJKSTRA WITH ACCIDENTS	3727	230	1457.35	0.164651913	-37.1	-2.54571654	1538	1.055340172		
35	**DIJKSTRA WITHOUT ACCIDENTS**	3727	230	1420.25				1265	0.890688259	0.164651913	15.6017858
	DIJKSTRA WITH ACCIDENTS	907	711	2469.95	0.073102292	1034.06	29.51076053	2479	1.003664042		
36	**DIJKSTRA WITHOUT ACCIDENTS**	907	711	3504.01				3773	1.076766333	0.073102292	6.789058069
	DIJKSTRA WITH ACCIDENTS	13681	769	2082.13	0.131808276	456.57	17.98440147	1526	0.732903325		
37	**DIJKSTRA WITHOUT ACCIDENTS**	13681	769	2538.7				1526	0.601095049	0.131808276	17.98440147
	DIJKSTRA WITH ACCIDENTS	371	389	988.5	0.01086031	746.3	43.01936823	821	0.83055134		
38	**DIJKSTRA WITHOUT ACCIDENTS**	371	389	1734.8				1422	0.819691031	0.01086031	1.307602459
	DIJKSTRA WITH ACCIDENTS	32483	835	1171.14	0.436448731	620.86	34.64620536	1307	1.116006626		
39	**DIJKSTRA WITHOUT ACCIDENTS**	32483	835	1792				2782	1.552455357	0.436448731	28.1134481
	DIJKSTRA WITH ACCIDENTS	2275	1984	9625.58	0.038497035	645.79	6.287282028	6639	0.689724671		
40	**DIJKSTRA WITHOUT ACCIDENTS**	2275	1984	10271.37				6689	0.651227636	0.038497035	5.581507679

First test results When the column "ATTEMPT" is marked in red, this means overal better performance in terms of suitability of the accidents non-optimised algorithm, viceversa in green.

ATEMPT	ALGORITHM	ID START	ID END	LENGTH m	SUITABILITY SCORE DIFFERENCE	LENGTH DIFFERENCE metres	LENGTH % DIFFERENCE	TOTAL SUITABILITY	SUITABILITY SCORE	SUITABILITY SCORE DIFFERENCE	% SUITABILITY SCORE DIFFERENCE
	DIJKSTRA WITH ACCIDENTS	710	4163	1681.07	0.015837075	-2.19	-0.130274171	1987	1.181985283		
41	DIJKSTRA WITHOUT ACCIDENTS	710	4163	1678.88				2011	1.197822358	0.015837075	1.322155533
	DIJKSTRA WITH ACCIDENTS	3030	19075	3424.81	0.549569232	302.7	8.12070256	3321	0.969688829		
42	DIJKSTRA WITHOUT ACCIDENTS	3030	19075	3727.51				1566	0.420119597	0.549569232	56.67480283
	DIJKSTRA WITH ACCIDENTS	30160	21668	8841.73	0.267199556	2021.32	18.60729721	7207	0.815111975		
43	DIJKSTRA WITHOUT ACCIDENTS	30160	21668	10863.05				5952	0.547912419	0.267199556	32.78071778
	DIJKSTRA WITH ACCIDENTS	3472	8837	3017.95	0.032207129	283.79	8.595164974	3396	1.125267152		
44	DIJKSTRA WITHOUT ACCIDENTS	3472	8837	3301.74				3609	1.093060023	0.032207129	2.862176204
	DIJKSTRA WITH ACCIDENTS	3005	9063	2387.03	0	0	0	977	0.409295233		
45	DIJKSTRA WITHOUT ACCIDENTS	3005	9063	2387.03				977	0.409295233	0	0
	DIJKSTRA WITH ACCIDENTS	22961	107	2680.71	0.240813012	656.26	19.66634402	2343	0.874022181		
46	DIJKSTRA WITHOUT ACCIDENTS	22961	107	3336.97				2113	0.633209169	0.240813012	27.55227696
	DIJKSTRA WITH ACCIDENTS	6498	9121	4180.26	0.108115885	53.81	1.270881209	3478	0.832005665		
47	DIJKSTRA WITHOUT ACCIDENTS	6498	9121	4234.07				3065	0.72388978	0.108115885	12.99460923
	DIJKSTRA WITH ACCIDENTS	5541	6525	3770.85	0.13747864	390.32	9.380054167	3411	0.904570588		
48	DIJKSTRA WITHOUT ACCIDENTS	5541	6525	4161.17				3192	0.767091948	0.13747864	15.19822131
	DIJKSTRA WITH ACCIDENTS	903	8550	5355.58	0.196804858	856.46	13.78709731	5944	1.109870453		
49	DIJKSTRA WITHOUT ACCIDENTS	903	8550	6212.04				5672	0.913065595	0.196804858	17.73223687
	DIJKSTRA WITH ACCIDENTS	8012	8464	2527.93	0.082936316	649.85	20.44981087	1387	0.548670256		
50	DIJKSTRA WITHOUT ACCIDENTS	8012	8464	3177.78				1480	0.46573394	0.082936316	15.11587606

First test results — When the column "ATTEMPT" is marked in red, this means overal better performance in terms of suitability of the accidents non-optimised algorithm, viceversa in green.

Appendix
IX

User requirements survey questions

Page 1

1) **What is your age?**	
Under 16	
16-25	
26-40	
41-65	
+65	

2) **In a week of you everyday routine how frequently do you cycle?**	
Never	
Only weekends	
1 day per week	
Everyday except weekends	
Between 3 and 4 days including weekends	
Everyday including weekends	
Between 3 and 4 days except weekends	

3) **"The roads you usually travel by bicycle are safe":**	
Strongly agree	
Neither agree nor disagree	
Mostly agree	
Mostly disagree	
Strongly disagree	

4) **Which, among these solutions, do you think could improve cycling safety? (choose up to 2 answers)**	
Web based map service showing cycling accidents hot spots	
Web based map service showing cycling accidents hotspots and safest route planner	
Mobile application showing cycling accidents hot spots	
Mobile application showing cycling accidents hotspots and safest route planner	
Mobile application that shows and warns cyclist when approaching accidents hotspots while cycling on roads	

5) **"A mobile application that warns cyclists when approaching accidents hotspots while cycling on roads would be useful for those who are not familiar with the road they are cycling"**	
Strongly agree	
Mostly agree	
Neither agree nor disagree	
Mostly disagree	
Strongly disagree	

6) **If you chose a mobile application that would warn you in case of danger while cycling, which alerting system you would prefer?(choose up to 2 answers)**	
Mobile vibration	
Speaker sound effect	
Headphones sound effect	
Visual (mobile kept on the handlebar)	
I don't know	
None of the previous (Please Specify)	

7) **"If I had a mobile application alerting of upcoming dangers while cycling I would keep my phone in a forearm pocket"**	
Strongly agree	
Mostly agree	
Neither agree nor disagree	
Mostly disagree	
Strongly disagree	

8) Add any comment you think relevant

Appendix
X

WebGIS survey questions

WEB GIS TESTING SURVEY

1. In a week of your everyday life, how often do you cycle?

Never

Only weekends

1 day per week

Between 2 and 4 days except weekends

Between 2 and 4 days including weekends

Everyday except weekends

Everyday including weekends

2. According to your conception of risk and your daily routine shifts, are you aware of the location of more risky points, in terms of cycling accidents incidence, in the area of the City of Edinburgh?

Yes

No

3. QUESTION 3

	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
If you answered no to question 2 go to question 4, otherwise please respond to this question. "The web application displays accidents where I expected them to be". How much do you agree with this sentence?					

4. QUESTION 4

	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
Respond only if you answered no to question 3. "I am now more aware of the location					

of cycling accidents in the City of Edinburgh area", how much do you agree with this sentence?

5. QUESTION 5

	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
"The route elaborated by the web service is effective in avoiding cycling risks". How much do you agree with this sentence?					

6. QUESTION 6

	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
"Once seen the routing planner results, next time I would consider to use the route suggested by the planner". How much do you agree with this sentence?					

7. If you anwered "Strongly agree" or "Disagree" to question 7. Could you plese briefly explain why you would not consider the suggested route?

8. If you had to choose one route between our web service and cycleStreets, which one would you choose?

Custom web service

Cyclestreets

No preference

9. In case you did not respond "No preference" could you please briefly explain some reasons of your preference?

10. How do you generally evaluate the web service

Very Good

Good

Neither good nor bad

Bad

Very bad

What improvements would you suggest?

Done

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